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STRUCTURAL INFORMATIONS ON THE KEROGEN OF THE HUNGARIAN OIL SHALE

M. HETÉNYI and K. SIROKMÁN

INTRODUCTION

Geo-organic materials, among others the oil shales themselves, are extremely complex. Their chemical structure is recently hardly known and concerning the kerogen of the highly vexed oil shale of Green River (USA) only a working modell of ever changing character can be even established [YEN, 1976].

The basis of the method of structure research is the degradation of kerogen into smaller structural units. The most wide-spread degradation method is the oxidation and the most frequently but not solely used oxidation medium is the alkaline potassium permanganate. Based on the structural units formed during oxidation conclusions are tried to be drawn to the monomers forming the kerogen. In case of a given kerogen and according to the parameters of isolation and degradation procedure as well as to the applied analytical methods various results can be obtained, thus the conclusions of different authors are not always the same. Out of the forming compounds numerous ones can be produced by the oxidation of mineral components thus their removal from the kerogen is highly significant [DJURIĆIĆ *et al.* 1971]. The mode of the degradation procedure, *i.e.* it is carried out in one step or stepwise, leads to other conclusions. The temperature, the duration as well as the fact that the formed Mn(IV)-oxide is removed after each step or will be removed only after the completion of the whole degradation process, are only a few factors among those which may influence the composition of the product formed in this way.

The compounds produced during artificial decomposition are already rather complex, all the more so since these are not compounds but compound groups. Their analysis depends on the applied techniques and on the resolution capacity of the applied instruments. E.g. having analyzed the Green River kerogen after oxidation by means of gas-liquid chromatography significant quantity of straight-chain aliphatic structures was found which have been recently identified by means of proton-NMR-spectroscopy mostly as fused-ring cycloalkanes [YOUNG and YEN, 1977].

Though among the kerogens deriving from different localities and being of different ages and origin considerable differences may exist concerning their structures, the kerogens known so far and based on their oxidation behaviour can be assigned to several groups and those being assigned to the same group are nearly of the same structural built-up.

As to the working model mentioned above the Green River kerogen is a multipolymer, a non-uniform three-dimensional gel-network which is inhomogeneous due to its bio- and diagenesis. The multipolymer is built up by two kinds of monomers: by difunctional bridges and by multifunctional components. MURPHY *et al.* [1971] who investigated also this kerogen, suggest it to consist of a central nucleus and of a periphery which is more advantageous from the point of view of degradation effects. According to DJURIČIĆ [1971] the nucleus is built up by long polymethylene bridges.

The kerogen "tasmanite" is built up also by a nucleus and by the joining chains. The nucleus is of aromatic structure, its chains consist mostly of disordered, undersaturated hydrocarbon polymers [SIMOINET and BURLINGAME, 1973].

The kerogen of the Aleksinac oil shale of Yugoslavia is so highly heterogeneous that it consists of two structurally also different organic materials which has been proved both by chemical and by micropetrographic measurements. One part is humic, the other (being of greater amount) is more resistent and of bituminous character [VITOROVIĆ *et al.*, 1973]. This bituminous part consists of relatively long aliphatic chains which are bound by cross-bonds [STEFANOVIĆ *et al.*, 1959].

In this paper the partial results of the oxidation of kerogen of the Hungarian oil shale by potassium permanganate will be discussed. This oil shale was discovered by the co-workers of the Hungarian State Geological Institute [JÁMBOR Á. *et al.*, 1976]. The investigated sample derives from the borehole Put—7, in the environment of Pula. In the course of the degradation investigations of the kerogen we tried to assign it to any of the types mentioned above and to find similarities with other thoroughly investigated kerogens of oil shales, respectively. In favour to do this an oxidation and isolation method has been chosen which has been applied to the degradation of several different kerogens. Thus, the method of VITOROVIĆ *et al.* [1973] was followed. The organic acids formed during the analyses have been analyzed by means of infrared spectroscopy and gas-liquid chromatography.

EXPERIMENTAL

The sample of the Hungarian oil shale was placed at our disposal by the Hungarian State Geological Institute. The results of DTA and IR-investigations on Hungarian oil shale kerogen were reported by GY. GRASSELLY, M. BERTALAN and CS. SAJGÓ [1977].

The raw sample was ground and sieved down to mesh 100, than the soluble fraction was removed in Soxhlet extractor. The extraction was carried out by chloroform (Bit—A) resp. by the mixture of benzene: acetone: methanol (75:15:15; BAM). Having removed the soluble fraction the kerogen was separated from the mineral components by physical method, *i.e.* in aqueous solution of calcium chloride ($d=1.19$). The degree of purity of the kerogen was controlled by density and ash-content measurements. The characteristic features of the bitumen fractions as well of the kerogen are summarized in Table 1.

3.5 g kerogen (*i.e.* 3.25 g organic matter) was step-wise oxidized by alkaline potassium permanganate. The relationship between the time of oxidation and the oxidizing agent is shown in *Fig. 1.* In each step 1.25 g potassium permanganate was added in 100 ml potassium hydroxide of 1.6% and it was kept on water-bath of 60° C till the red colour of potassium permanganate disappeared and the brown colour of manganese dioxide occurred. The soluble products formed during oxidation were removed in order to prevent their further transformation. The solid part containing the unoxidized kerogen and the manganese dioxide was oxidized again in the second step under similar conditions described above. Since in the sixteenth step the potassium permanganate was not reduced already after 50 hours, oxidation was regarded to be complete. After the final oxidation step the surplus of po-

TABLE 1

Analytical data on organic matter of Hungarian oil shale

	Bitumen-A	Bitumen-BAM	Kerogen
		Original sample	
Quantity %	3.95	2.01	11.00
		Organic matter	
C %	68.90	74.80	73.60
H %	12.10	11.60	11,70
H/C atomic ratio	2.0	1.8	1.9
Ash %			8.0
Specific gravity g/cm³			1.1

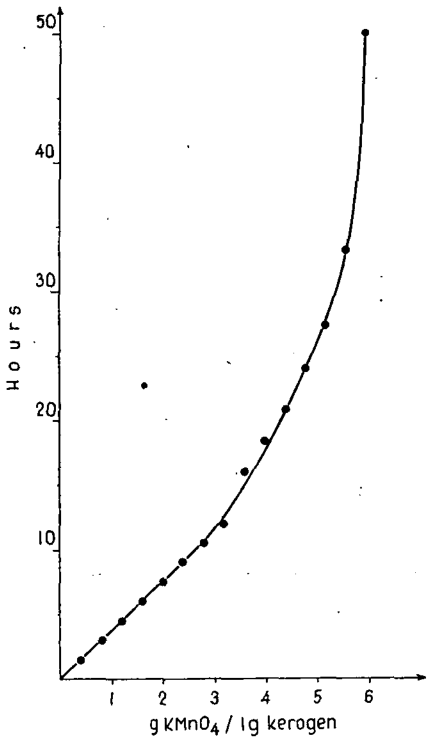

Fig. 1. Rate of oxidation, based on one gram of kerogen

tassium permanganate and the manganese dioxide were reduced by sulphur dioxide. The solid residue is about 5 per cent of the original organic matter.

In each steps the soluble products were treated separately *(Fig. 2)* following

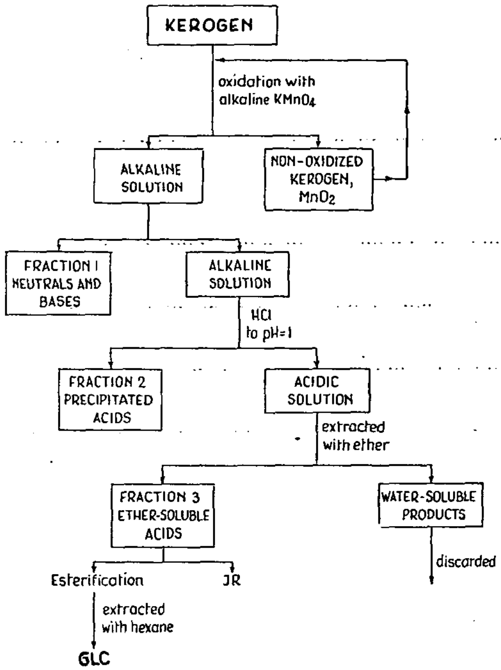

Fig. 2. Schematic outline of the experimental procedures

the method as below: the neutral and basic products were removed by ethereal extraction (1st fraction). The alkalic solution was acidifyed by hydrochloric acid to pH=1, the precipitated acids were removed by filtration (2nd fraction). The acid solution was etherifyed again collecting in the ethereal fraction the ether-soluble acids (3rd fraction). The total quantities of each fractions as well as the oxidation residue characterizing the kerogen of the Hungarian oil shale and the two checking samples are summarized in Table 2. The quantities of the fractions were determined in each steps and were plotted against the number of oxidation steps *(Fig. 3)*.

TABLE 2

Products and residue recovered by oxidation of different oil shales

Oil shales	Oxidation products Fraction 1 %	Fraction 2 %	Fraction 3 %	Residue %	Steps
Torbanite (Australia)	0.54	0.66	15.80	66.20	13
Aleksinac (Yugoslavia)	0.75	24.90	35.10	1.16	9
Oil shale (Hungary)	19.00	46.00	5.00	5.00	16
Green River (USA)	—	46.00	27.00	—	9

The ether-soluble acids were esterifyed by means of hydrochloric acidic methanol under carbon dioxide atmosphere during 120 minutes and treated at 80° C, then these were extracted by hexane and the hexane-soluble esters were analyzed by means of gas-liquid chromatograph (GLC).

Parameteres of the GLC: JEOL IGC—20K type; colonna: SP 23—40; temperature: 205° C.

The infrared spectroscopic records were made by UNICAM SP—200 equipment.

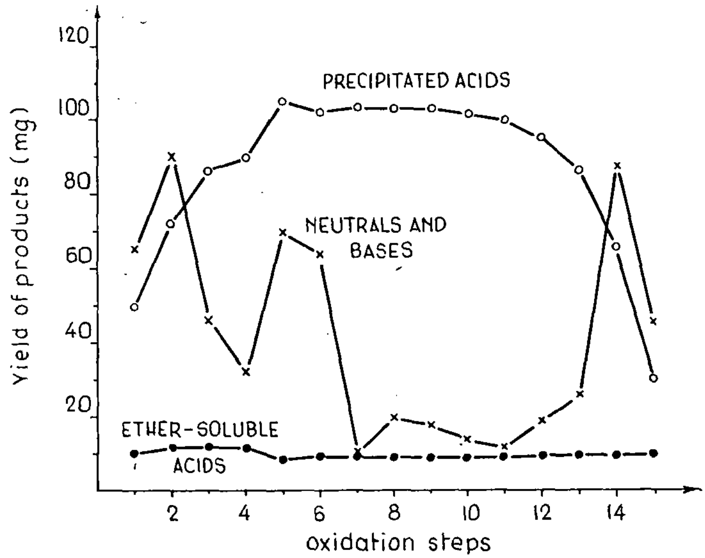

Fig. 3. The yield of oxidation products obtained from each step

RESULTS

The IR-records made from the oxidation products of kerogen as well as from the oxidation rest do not refer to the presence of aromatic acids. The IR-records made from the ether-soluble fractions of the steps 5 and 14 and from the non-oxidized residue are shown in *Fig. 4.* In Table 3 the common and most characteristic peaks of kerogens as well as their interpretation [SAXBY, 1976] are demonstrated. This Table shows also the evaluation of the most characteristic peaks of the IR-spectra of *Fig. 4,* as well as the checking coorongite, resp., its adequate wave number values, after CANE [1969]. The characteristic aromatic peaks (3000—3080 cm^{-1}, 1500—1520 cm^{-1}) are absent both in the spectra of the unoxidized residue and in those of the acids formed during oxidation similarly to those of coorongite. Though a smaller peak occurs at 740—850 cm^{-1} being attributed to aromatic rings by SAXBY but it is well-known that this range is characteristic not only of the compounds mentioned above, but of other inorganic and organic bond types. Thus, it cannot be accepted alone to prove the aromatic character.

As it is known, the oxidation method outlined above was adopted from coal chemistry to investigate the kerogens. During oxidation of coals under similar

TABLE 3

Infrared spectra of kerogens and ether-soluble acids derived from Hungarian oil shale kerogen

Kerogens (by SAXBY) cm^{-1}	Characteristic bands of infrared spectra of Hungarian oil shale kerogen			Coorongite (by CANE) cm^{-1}
	5. step cm^{-1}	14. step cm^{-1}	Residue cm^{-1}	
3310—3390 OH and NH bonds		3390—3500	3000—3850	3360
3000—3080 aromatic CH bonds	—	—	—	—
2900 aliphatic CH bonds	2900—2950	2900—2920	2920	2860—2950
1680—1745 C=0 bonds	1680—1710	1680—1710	1710—1720	1710—1735
1580—1650 C=C bonds H_2O deform. conj. C=0 bonds	1630		1620	1585
1500—1520 aromatic rings	—	—	—	—
1400—1460 aliphatic CH_2 and CH_3 groups	1410—1470	1410—1470	predominance of inorganic components	1460—1470
1370—1380 CH_3 and cyclic CH_2 groups	1380			1380
1090—1250 C—O bonds	1090—1250	1090—1250		1085—1140
890—980 C=C bonds	940			
740—850 condensed aromatic rings	790	—	790—810	840
720—725 aliphatic chains greater than C_4	720—730	720	725	725

conditions compounds of aromatic character are formed and the ratio of which increases with the progressing coalification. Consequently, the presence of aromatic acids among the oxidation products of kerogen relates to the fact that this organic matter contains also humic components while the absence of the aromatic acids is characteristic rather of the kerogens of algal origin [CANE, 1976]. Accordingly, the kerogen investigated by us seems to be of pure algal origin. This statement is supported by the GLC measurements, too, which also did not relate to the presence of aromatic acids.

On the basis of the quantity of the unoxidizable residue the kerogens of the oil shales can be assigned to two groups. It is characteristic of the first group that

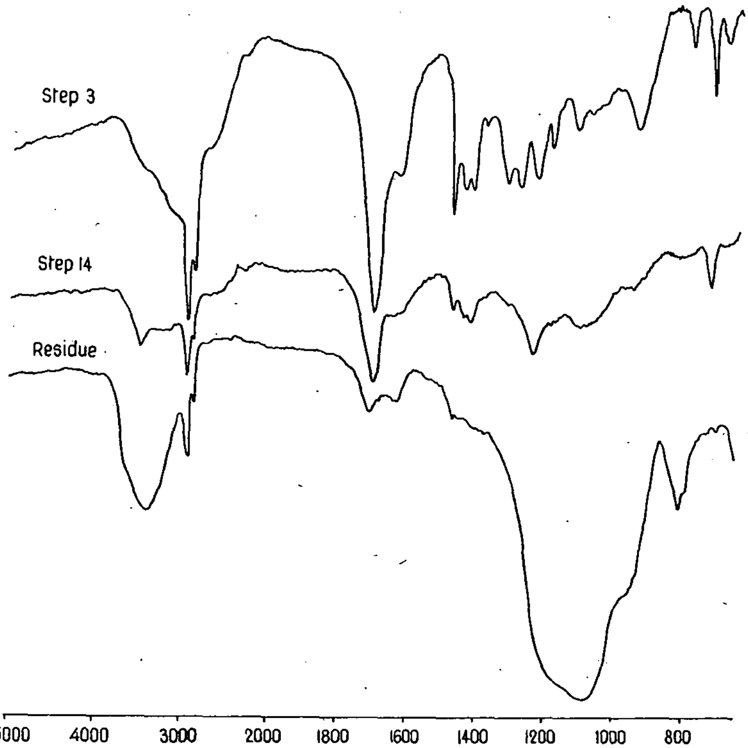

Fig. 4. IR-spectra of the unoxidized residue and ether-soluble acids obtained in the 5. and 14. oxidation steps

it can be nearly completely oxidized, e.g. the Green River oil shale (USA), kukersite kerogen (Soviet Union). The kerogens of the other group, e.g. the torbanite (Australia) are highly resistent to oxidation. According to our measurements the oxidation residue of the kerogen of the Hungarian oil shale amounts to about 5 per cent, *i.e.* it is assigned to the first group. According to CANE [1976] resistance is characteristic of the kerogens which derive from algal hydrocarbons, while the good efficiency of oxidation is characteristic of the kerogens derived from algal fatty acids. Thus, the kerogens of the Green River oil shale and those of the Hungarian oil shale might originate from algal fatty acids. The precursor of kerogen of the Hungarian oil shale is the alga *Botryococcus braunii* [JÁMBOR and SOLTI, 1976]. The lipid content of the freshwater algae amounts to about 60 to 70 per cent in the so-called "unfavourable environment" being poorer in nitrogen salts [ABELSON, 1959]. The lipid content may consist of more than 80 per cent fatty acid. Thus, the fatty acid content of the alga might serve as the source of kerogen. Most of the fatty acids is unsaturated, consisting mainly of C_{16} and C_{18} and C_{14} and C_{20} are also found in relatively greater quantities. In the accumulation environment of the Hungarian oil shale the water level fluctuation of the small area, and parallel with this the extension and conditions of vegetation undergoing also frequent changes, have considerably influenced the oxygen production. The flourishing of vegetation increased the oxygen quantity, its extinction produced reductive environment [RAVASZ, 1976]. Immediately after the deposition following the destruction of the alga, *i.e.* when integrity of the cell wall ceased, the oxygen attacked the fatty acids and produced a highly polymerized kerogen as it has been evidenced by the results of the analyses performed by alkaline potassium permanganate oxidation. The high degree of polymerization is evidenced also by the fact that though kerogen is oxidizable nearly quantitatively, the oxidation is slow under the given experimental conditions. In *Fig. 1* the time of oxidation is plotted against the quantity of the oxidizing agent. When comparing its oxidation with that of the Yugoslavian Aleksinac oil shale [VITOROVIĆ *et al.*, 1973] — in which the duration continuously increases from 5 to 60 minutes in the first six steps, and this is more than 60 minutes already in the first step in case of the Hungarian oil shale; the oxidation time is the same in the first six steps and a slight increase between the seventh and twelwth and a sudden one after the twelwth step can be observed — it can be assumed that the Hungarian oil shale is probably of strongerly polymerized structure.

The elementary analysis and technological test of the oil shale lead to similar conclusions. The average oxygen content amounts to about 15 per cent which is a relatively high value. On the basis of the high bitumen content as compared to the soluble fraction and obtained by the FISHER-assay, the Hungarian oil shale has been qualified as an oil shale of progressed polymerization and of high kerogen content [ARATÓ and BELLA, 1976].

The fact that the quantity of the ether-soluble acids obtained during the oxidation is relatively small, relates also to high-grade polymerization. In Table 2 the products of oxidation of other kerogens performed in the same way, *i.e.* those of the Australian torbanite, of the Yugoslavian oil shale [DJURIČIĆ *et al.* 1971], as well as the oxidation products of the Green River oil shale's kerogen obtained by different method but also with alkaline potassium permanganate [YOUNG and YEN, 1977] are summarized. Our measurement results concerning the oxidation of kerogen of the Hungarian oil shale are reported also in Table 2. When comparing the data it can be seen that during the oxidation of kerogen of the Hungarian oil shale relatively great amounts of solid acid are formed (fraction 2) while the third fraction is conspicuously small. According to VITOROVIĆ et al. [1973] the second and third fractions are the same concerning their chemical character. This was evidenced by the fact that having oxidized the second fraction by potassium permanganate, ether-soluble acids were obtained again. Following the previous procedure the solid acids deriving from the third step of oxidation of the Hungarian oil shale, ether-soluble acids were obtained by the repeated oxidation which similarly to the other products were analyzed as demonstrated in *Fig. 2.* The gaschromatograms of the ether-soluble acids formed in the 2nd, 6th and 12th steps are shown in *Fig. 5* which represent three phases of the oxidation process. Most of the products is a straight-chain aliphatic monocarbonic acid, between C_{14} and C_{24}. In harmony with the IR-spectra aromatic carbonic acids could not be detected. During similar investigations carried out in kerogens of other oil shales straight-chain aliphatic monocarbonic acids were also obtained in large quantities. E.g. having oxidized the Yugoslavian Aleksinac oil shale [VITOROVIĆ *et al.* 1973] monocarbonic acids of C_8—C_{26} were identified. On the basis of the gas chromatograms of the kerogen's oxidation products of the Green River oil shale, the oxidation products seemed to be mostly straight-chain aliphatic components [YOUNG and YEN, 1977]. The coorongite was degraded by potassium permanganate [CANE, 1969]. The coorongite represents a very early stage of the formation of algal kerogens and can be regarded as the peat-state during the coalification of algal shales. Among the acidic products mostly mono- and dicarbonic acids of C_{16}—C_{22} were identified.

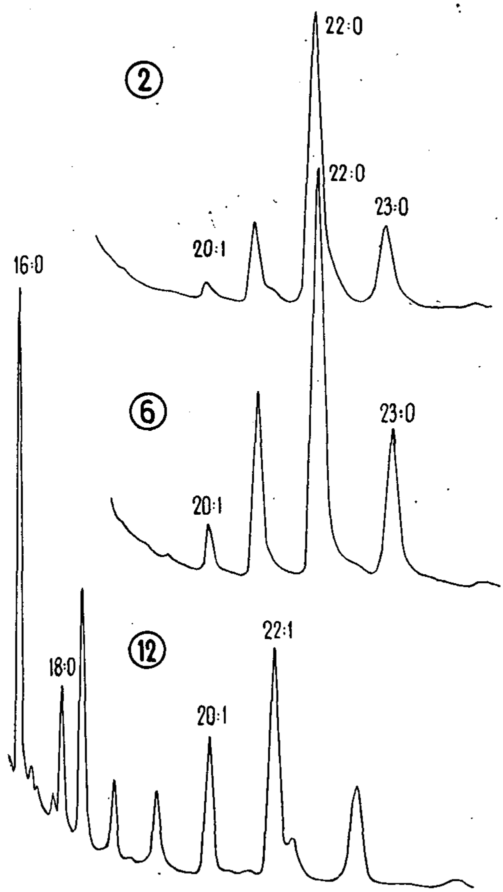

Fig. 5. The gas chromatogram of the ether-soluble acids obtained in the 2., 6. and 12. oxidation steps

Investigating the produced monocarbonic acids as a function of the oxidation time, in the first six steps (in which the oxidation time is shorter and is the same) the gas chromatograms seem to be the same. This is illustrated in *Figs. 5a* and *5b* were the gas chromatograms of the ether-soluble acids of the 2nd and 6th steps are shown. Major part of the oxidation products is $C_{22:0}$, in smaller amounts $C_{23:0}$ and $C_{21:1}$ aliphatic monocarbonic acids are also found. (The mode of designation is as follows: $C_{N:M}$, where N denotes the atom-number of C, M is the number of double-bonds.)

From the 7th step the analytical results of the GLC analyses show some changes in addition to the increase of the oxidation time. Since from this step the gas chromatograms are roughly the same in all steps, only one of them will be presented *(Fig. 5c)*. When comparing this with the *Figs. 5a* and *5b* it is seen that in the second part of oxidation the composition of the ether-soluble acids is more variegated. Mostly $C_{16:0}$ and $C_{22:1}$ as well as $C_{20:1}$ and $C_{18:0}$ aliphatic monocarbonic acids were identified.

The further oxidation of the solid acids obtained in the 3rd step and investigating the ether-soluble acids by GLC mostly $C_{22:1}$ and $C_{20:0}$ aliphatic monocarbonic acids were identified. When comparing this result with the analysis of the ether-soluble acids obtained in the 3rd step, it is obvious that during repeated oxidation the oxidation products show a composition being rather similar to the original one.

Based on these results it seems to be probable that the kerogen of the Hungarian oil shale is highly polymerized and is a "macromolecule" built up by aliphatic hydrocarbons as evidenced by the GLC analyses.

SUMMARY

The Hungarian oil shale's kerogen was degraded into smaller and simpler compounds which are, however, in structural relation with the complex starting material.

The products relate to the structure of kerogen, the character of the products as well as the efficiency of degradation conclusions can be drawn concerning the precursor and possible source of the organic matter, further the type of the organic compounds.

Degradation was carried out by alkaline potassium permanganate which reacts with the carbon atom of functional groups or with the neighbouring one.

Oxidation was carried out step by step in favour to prevent the further oxidation of the products.

In the 16th step the duration of oxidation is more than 50 hours, thus the process was regarded to be completed, all the more so since in this stage only 5 per cent of the organic matter remained unoxidized.

Investigating the unoxidized and oxidized products compounds of aromatic character were not detected either by IR or by GLC method. This relates to the fact that the organic matter investigated is practically of algal origin and does not contain humic compounds. According to the classification of CANE [1976] it is assigned to "kerogen—A". On the basis of the efficiency of oxidation (which proved to be very good, *i.e.* unoxidized kerogen hardly remained) a finer subdivision was also made, thus the material is assigned to the type *A(i)*, *i.e.* it may derive mostly from algal fatty acids.

Taking into account that the precursor of the Hungarian oil shale is the alga *Botryococcus braunii,* its C_{16} and C_{18}, mostly unsaturated fatty acids were probably the source material of the kerogen.

The unsaturated fatty acids were highly polymerized just after the destruction of the algae and produced a complex "macromolecule". In addition to the elementary analysis of the oil shale (considerable oxygen content) and to the technological analyses (results of the FISHER-assay) the fact refers also to this fact that though it can be practically totally oxidized by alkaline potassium permanganate the single

oxidation steps, however, need much more time than, e.g. in case of the Yugoslavian oil shale oxidized in a similar way.

The distribution of the oxidation products among the three fractions supports also the high-grade polymerization. Relatively small amount of ether-soluble acids was formed though the chemical character of the solid acids being the major part of the degradation products, is rather similar to that of the ether-soluble acids. The similarity of the two fractions is evidenced by the fact that repeated oxidation on the solid acids resulted in ether-soluble acids again.

Analyzing the ether-soluble acids produced by oxidation by means of GLC considerable quantity of aliphatic monocarbonic acid was detected. Thus, their change was followed as a function of progressing oxidation. No conspicuous change was determined during the oxidation process, the aliphatic monocarbonic acids are C_{16} to C_{24}, they are saturated in general or contain at least one unsaturated bond. Some change can be observed from the 7th step; before this the major part of the products is $C_{22:0}$ and $C_{23:0}$, while in the second part of oxidation mostly $C_{16:0}$ and in smaller quantity $C_{18:0}$ aliphatic monocarbonic acids were identified in addition to the $C_{22:1}$ and $C_{20:1}$ ones.

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REFERENCES

ABELSON, P. H. [1959]: Geochemistry of organic substances. — In: Researches in Geochemistry edited by P. H. Abelson. J. Wiley and Sons, Inc., Publishers. p. 79—104.

ARATÓ, K. and M. BELLA [1976]: Results of technological and chemical analyses of the oil shale of Pula and Gérce (Transdanubia, Hungary). — Annual Report of the Hungarian Geological Institute of 1974. p. 287—300.

CANE, R. F. [1969]: Coorongite and the genesis of oil shale. — Geochim. et Cosmochim. Acta *33*, p. 257—265.

CANE, R. F. [1976]: The origin and formation of oil shale. — In: Oil shale, edited by T. F. Yen an G. V. Chilingarian. Elsevier Scientific Publishing Company p. 27—61.

DJURIĆIĆ, M., R. C. MURPHY, D. VITOROVIĆ and K. BIEMANN [1971]: Organic acids obtained by alkaline permanganate oxidation of kerogen from the Green River (Colorado) shale. — Geochim. et Cosmochim. Acta *35*, p. 1201—1207.

DJURIĆIĆ M. V., D. VITOROVIĆ, B. D. ANDRESEN, H. S. HERTZ, R. C. MURPHY, G. PRETI and K. BIEMANN [1972]: Acids obtained by oxidation of kerogens of ancient sediments of different geographic origin. — Adv. in Org. Geochem., 1971 p. 305—321.

GRASSELLY, GY., M. BERTALAN and CS. SAJGÓ [1977]: Contributions to the knowledge of the Hungarian oil shale kerogen II. Result of preliminary DTA and IR-investigations on the kerogen of the oil shale occurrence at Pula. — Acta Miner. Petr., *XXIII/1*, p. 165—175.

JÁMBOR, Á. and SOLTI, G. [1975]: Geological conditions of the Upper Pannonian oil shale deposit recovered in the Balaton Highland and at Kemeneshát. — Acta Miner. Petr., *XXII/1* p. 9—28.

JÁMBOR, Á. and G. SOLTI [1976]: Geological conditions of the Upper Pannonian oil shale deposit recovered in the Balaton Highland and at Kemeneshát (Transdanubia, Hungary). — Annual Report of the Hungarian Geological Institute of 1974. p. 193—220.

RAVASZ, CS. [1976]: Petrographic examinations of oil shale at Pula and Gérce. — Annual Report of the Hungarian Geological Institute of 1974. p. 221—246.

SAXBY, J. D. [1976]: Chemical separation and characterization of kerogen from oil shale. — In: Oil shale, edited by T. F. Yen and G. V. Chilingarian. Elsevier Scientific Publishing Company. p. 103—121.

SIMONEIT, B. R. and A. L. BURLINGAME [1973]: Carboxylic acids derived from Tasmanian tasmanite by extractions and kerogen oxidations. — Geochim. et Cosmochim. Acta *37*, p. 595—610

YEN, T. F. [1976]: Structural aspects of organic components in oil shales. — In: Oil shale, edited by T. F. Yen and G. V. Chilingarian. Elsevier Scientific Publishing Company. p. 129—147.
YOUNG, D. K. and T. F. YEN [1977]: The nature of straight-chain aliphatic structures in Green River kerogen. — Geochim. et Cosmochim. Acta *41*, p. 1411—1418.
VITOROVIĆ, D., M. V. DJURIČIĆ and B. ILIĆ [1973]: New structural information obtained by stepwise oxidation of kerogen from the Aleksinac (Yugoslavia) shale. — Advances in Organic Geochemistry 1971, p. 179—189.

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GEOCHEMICAL STUDIES OF SOME GRANITES FROM THE SOUTH WESTERN DESERT, EGYPT

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G. M. SALLOUM and M. M. ALY

ABSTRACT

The present work is the first detailed petrochemical and geochemical studies done on some 18 granitic rocks collected from the south Western Desert of Egypt. The petrochemical work includes complete chemical analyses of these rocks beside calculation of the CIPW norms, NIGGLI values, D. I., F. I. and M. I. Thirteen trace elements are quantitatively determined, these are: Ba, Rb, Sr, Y, Zr, Nb, La, Ce, Nd, Cr, Ni, Zn and Cu.

These chemical studies established the presence of five rock types: grey granite, Aswan-type granite, normal pink-red granite, strongly fractionated pink-red granite and syenite. It is concluded that the basement rocks of Egypt developed in the Eastern Desert and Sinai peninsula are extended across the Nile, mostly subsurface, in the southern parts of the Western Desert. To the first time, Aswan coarse granites are proved to occur in the south Western Desert. This makes them of much wider aereal distribution than previously known. On account of their peculiar chemical composition, Aswan plutonites can be grouped in a separate plutonic cycle.

INTRODUCTION

The southern parts of the Western Desert of Egypt particularly the Oweinat plateau and the neighbourhoods are regarded among the most remote areas in Egypt. This inaccessibility restricted the geological studies on the area so that only few geological works are available.

The pioneering works are those of LYONS [1894], BALL [1902], HUME [1908] and BEADNELL [1909] dealing with the geology of separate parts of this remote area. BALL and HUME works embody the results of quick reconnaissance survey across parts of the area under study. For almost half a century the results arrived at by these geologists remained the only geological data known about that area. ISSAWI [1968] paid much attention to the stratigraphy, lithological characteristics, structural relationships and sedimentary history of the rocks of this area, moreover he briefly studied the outcropped basement rocks encountered in the area although he sampled most of these rocks.

The present work is the first detailed geochemical studies done on the outcropping granitic masses occurring in the region lying west of the Nile at Abu Simbil till Oweinat plateau, *(Fig. 1)*. The importance of this work stems out from the fact that most of the mentioned area is difficultly accessible. The work includes the geologic setting of the granitic bodies, tectonic considerations, brief petrographic description of the hand specimens beside petrochemical and geochemical

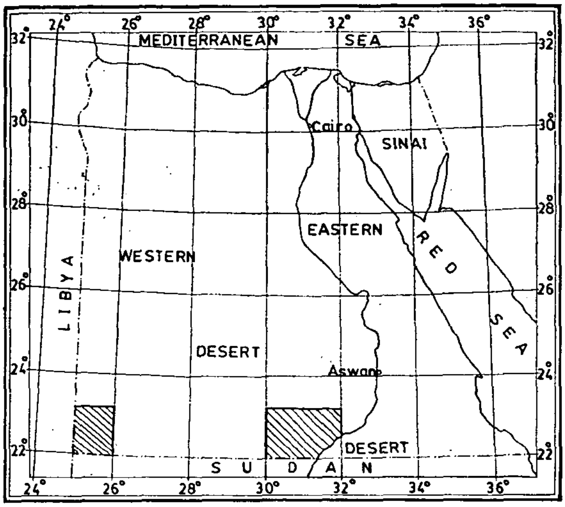

Fig.(1): Key map showing the sampled areas of granitic masses in the south Western Desert of Egypt.

Sampled areas.

investigations. The latter includes the quantitative determination of 13 major constituents: SiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, H_2O^+ and H_2O^-, beside the quantitative determination of 13 trace elements: Ba, Rb, Sr, Y, Zr, Nb, La, Ce, Nd, Cr, Ni, Zn and Cu.

CIPW norms, NIGGLI-values, differentiation indices, mafic indices and felsic indices are calculated for the 18 analyzed rocks. The present study shed some light on the various types of granitic rocks present in that remote part of the country beside giving an idea about their origin and mode of emplacement.

FIELD OCCURRENCE OF THE GRANITES

The granitic masses outcropping in the area rise about 500 m above the plain which rises gradually west in the direction of Gebel Oweinat whose elevation is 1114 m. At the extreme south western corner of the Western Desert, there occurs the Oweinat mountain which is composed mainly of older granitoids including the so-called grey granites beside some cataclased granites. But at the southern parts of Oweinat mountain, some younger granites are developed. The area west of Abu Simbil includes several outcrops of different types of pink-red or younger granites. Among these are Aswan granites, normal pink-red granites and strongly differentiated pink-red granites beside some granosyenites and syenites. *Fig. 2* and *3* are geological maps of the Oweinat area and the Dunqul-Abu Simbil area showing the different granitic exposures and the sampled localites.

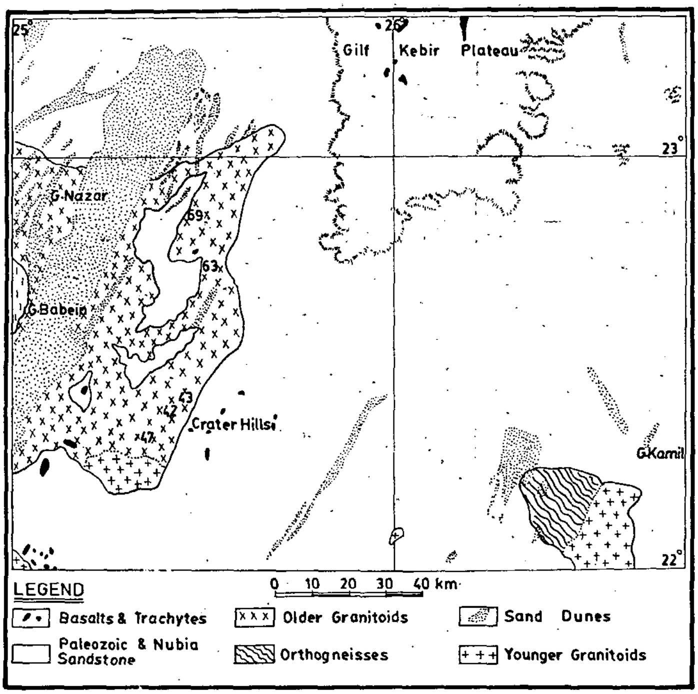

FIG-(2): RECONNAISSANCE GEOLOGICAL MAP OF OWEINAT AREA.
Sample Localities Are Indicated.

TECTONIC CONSIDERATIONS

The structural pattern of the area in question *i.e.* the area west of Abu Simbil till Oweinat is governed mainly by fault lines trending predominantly in an E—W direction and extending for distances ranging from few kilometers to more than 250 km. Along these major faults, block uplifting occurred resulting in the outcropping of some parts of the basement rocks. Another set of faults is noticed in the vicinity of the Nile and have N—S trend. These faults are generally of secondary importance in manifesting the structural framework of the area. Owing to the uplift of the basement rocks, the overlying sedimentary cover is tilted or uparched [Issawi, 1968].

The basement rocks of that part of the Western Desert are correlated with those outcropping in the Eastern Desert and Aswan region. Gravimetric survey [Geofizika, 1966] of the southern Western Desert has shown that the basement highs exist beneath the ground in the stretch of land between Aswan and Oweinat. The occurrence of several basement outcrops attest the presence of such a belt.

The E—W fault system is developed as a result of the block uplifting of the earth's crust of the south Western Desert and the contemporaneous regression of the Tethys towards the north direction. The Hercynian phase of tectonism plays the predominant role in the area under consideration and generally in the whole of the Western Desert. It is clear that the uplift movement started at the south

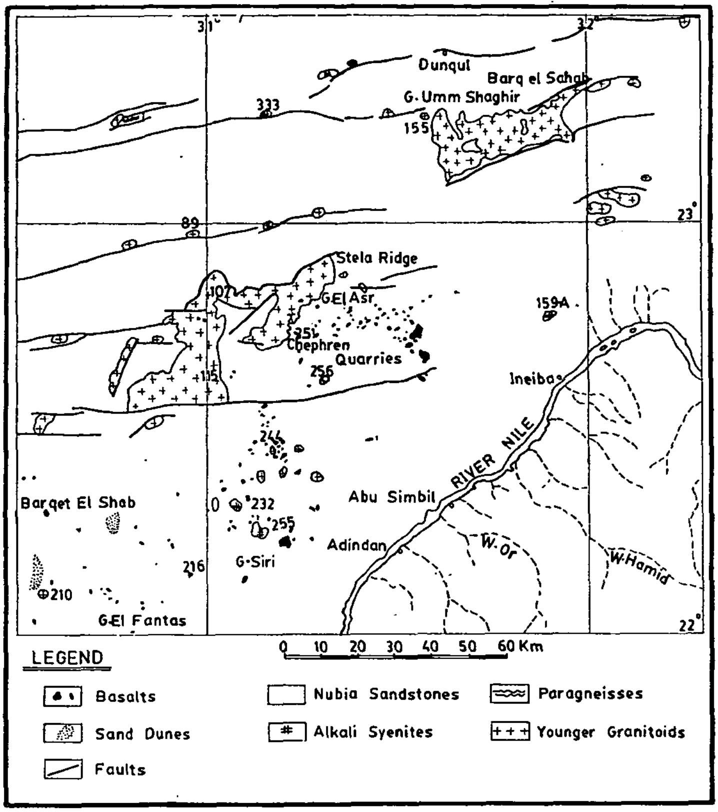

FIG.(3): GEOLOGICAL MAP OF THE DUNQUL – ABU SIMBIL AREA. Sample Localities Are Indicated.

and gradually moved towards the north and was accompanied by the regression of the Tethys and its shore line. The faults are rejuvenated from time to time.

PETROGRAPHIC DESCRIPTION

In the following paragraphs, brief petrographic description is given for the various types of granites that occur in the southern part of the Western Desert. The description includes the grey granites, Aswan-type granites, younger pink-red granites beside certain syenites.

Grey Granite:

This includes samples 42, 43, 47, 63 and 69. The rock is holocrystalline, medium to fine grained, tending to be grey in color but some pinkish varieties are present (sample 47). Some of the specimens are hard and not altered (sample 42), others are friable and weathered (sample 43).

Composed of plagioclase feldspars that constitute about 50% of the rock, fine anhedral quartz grains that reach about 30% of the rock beside some ferromagnesian minerals that amount to about 20%. The mineralogical character of the latter minerals varies with the specimen investigated. In some samples (43 and 63) it is mainly biotite, in others (sample 47) it is biotite with some hornblende while in sample 42, it is composed of small prismatic and black crystals of amphiboles.

The rocks in general develop no gneissic texture, however, sample 69 develops gneissic texture and being composed of green amphiboles that contain buff feldspars and violet quartz patches which are sometimes arranged alternatively in layers with the original greenish minerals.

Aswan-Type Granite:

This includes three samples 159-A, 232 and 244. This rock is holocrystalline, coarse grained, pink in color. Composed of pink potash feldspars with porphyritic crystals that attain 3.5 cm in length, white plagioclases, abundant quartz, rich in black mica sometimes associated with hornblende. Some samples (232 and 244) develop subparallel arrangement of biotite crystals, in other cases (sample 159-A) schlieren texture is developed. Sample 232 shows some kaolinization of the feldspars.

Pink-Red Granite:

This group of rocks includes eight granite samples with numbers: 89, 107, 115, 210, 216, 251, 256 and 333. It comprises different granite types such as: pink, red, porphyritic, gneissic, muscovite-bearing and biotite-bearing. The granites are holocrystalline, generally medium grained and pinkish in color. Some. rocks are hard and look not altered (e.g. sample 333), while others are weathered and cracked (e.g. sample 210).

Composed of pinkish feldspars mostly potash feldspars but may be mixed with a lower proportion of plagioclases together form about 60% of the rock. Quartz is the next abundant mineral and forms about 30%. Minor amount of ferromagnesian minerals is always present, this may be biotite as in samples 210 and 251, or muscovite (sample 216). Some red varieties of these granitic rocks (sample 333) show quite dropping amount of biotite.

Most of the rock samples develop typical granitic texture. However, sample 216 shows graphic texture, sample 251 develops porphyritic texture while sample 256 has gneissic texture. Schlieren patches may be present in few specimens like sample 210.

Syenite:

Two syenite samples are used in this study with numbers 155 and 255. The rock is holocrystalline, coarse or medium grained and pink in color, composed of pinkish feldspars including potash and plagioclases together amount to 70%, an abundance of biotite or amphibole (20%), beside a subordinate amount of quartz.

PETROCHEMISTRY

The complete chemical analyses expressed in weight per cent of the oxides for the 18 investigated rocks are given in Table 1. The same Table includes data of differentiation index (D.I.), felsic index (F.I.) and mafic index (M.I.). Table 2 on the other hand gives some reference analyses used for comparative purposes. Thus the Table reproduces the analyses of the high and low-Ca granites of TUREKIAN and WEDEPOHL [1961], a reference syenite [TUREKIAN and WEDEPOHL, 1961], typical grey, Aswan, normal pink-red and strongly differentiated pink-red granites as given by EL-SOKKARY [1970]. Table 3 gives CIPW norms of the same group of rocks while

TABLE 1

Complete chemical analyses (wt. %) of the investigated granitic rocks

Oxide	Grey Granite			Aswan-Type Granite					Sye-nite
	42	43	47	63	69	159-A	232	244	155
SiO_2	63.87	60.73	64.00	65.04	66.75	68.34	69.31	71.40	65.49
Al_2O_3	15.05	16.15	13.25	14.54	14.28	13.77	13.52	14.60	15.56
Fe_2O_3	1.37	1.84	4.76	1.50	2.03	1.17	2.49	Tr.	0.76
FeO	3.72	3.53	2.74	1.96	3.13	2.25	1.27	0.79	3.86
MnO	0.15	0.10	0.10	0.08	0.10	0.10	0.06	0.03	0.13
MgO	0.93	4.18	0.98	0.93	1.06	0.46	0.69	0.35	0.46
CaO	2.58	5.01	3.86	3.86	2.56	1.93	2.25	1.82	2.58
Na_2O	6.58	4.03	4.31	6.58	6.36	3.86	4.15	3.49	4.46
K_2O	2.80	2.10	3.71	3.62	2.00	6.27	4.10	4.95	4.53
TiO_2	0.73	0.56	0.55	0.51	0.61	0.17	0.21	0.12	0.73
P_2O_5	0.15	0.22	0.17	0.11	0.11	0.18	0.17	0.07	0.09
H_2O^+	2.40	1.86	1.45	0.95	1.15	1.18	1.25	1.18	1.69
H_2O^-	0.15	0.28	0.20	0.30	0.25	0.20	0.29	0.22	0.31
Total	100.48	100.59	100.08	99.98	100.41	99.88	99.76	99.02	100.65
D.I.	9.86	5.10	9.69	9.81	9.58	14.18	12.16	13.72	11.84
F.I.	79.65	56.92	69.47	74.06	77.71	85.38	80.10	83.75	79.35
M.I.	87.30	61.53	90.25	82.11	85.75	90.18	86.67	74.39	92.65

TABLE 1.: Continued

Oxide	Sye-nite	Pink-Red Granite							
	255	89	107	115	210	216	251	256	333
SiO_2	63.99	73.03	73.19	71.35	74.27	71.53	71.95	72.83	77.87
Al_2O_3	12.50	13.25	13.49	13.52	14.12	13.52	13.01	14.28	10.24
Fe_2O_3	6.92	1.44	1.16	0.83	Ttr.	0.82	2.17	0.74	1.73
FeO	0.39	0.39	0.19	0.49	0.79	0.29	1.76	0.98	0.28
MnO	0.11	0.02	0.01	0.02	0.03	0.01	0.07	0.05	0.05
MgO	0.69	0.46	1.19	0.23	0.39	0.23	0.46	0.46	0.22
CaO	1.29	1.93	1.61	1.29	2.00	1.61	0.64	1.29	0.65
Na_2O	6.79	3.86	2.97	2.59	2.80	2.26	3.07	4.15	3.08
K_2O	4.48	3.62	4.39	8.19	4.91	7.57	5.11	4.58	3.89
TiO_2	0.29	0.21	0.11	0.12	0.08	0.06	0.31	0.30	0.25
P_2O_2	0.09	0.15	0.14	0.08	0.03	0.13	0.16	0.10	Tr.
H_2O^+	1.88	1.13	1.06	0.86	1.02	1.32	0.93	0.88	1.18
H_2O^-	0.28	0.24	0.22	0.18	0.31	0.24	0.19	0.31	0.33
Total	99.70	99.73	99.73	99.75	100.75	99.59	99.83	99.95	99.77
D.I.	12.07	12.71	13.17	16.85	13.95	16.13	14.70	13.78	14.76
F.I.	90.50	80.94	83.55	90.46	81.16	87.38	93.41	88.21	92.31
M.I.	92.45	82.39	57.14	87.27	71.76	85.11	91.17	82.05	91.02

Table 2

Analyses (wt.%) of the reference high-Ca, low-Ca granite, syenite beside typical grey, Aswan normal pink-red and strongly differentiated pink-red granites

Oxide	High-Ca[1]	Low-Ca[2]	Syenite[3]	Grey[4]	Aswan[5]	Normal Pink-Red[6]	Strongly Diff.[7]
SiO_2	67.23	74.29	62.30	67.84	70.29	74.08	75.41
Al_2O_3	15.50	13.61	16.63	14.34	13.79	13.14	13.18
Fe_2O_3	4.23*	2.03*	5.25*	—	0.43	0.30	0.31
FeO				3.53	2.00	1.13	0.30
MnO	0.07	0.05	0.11	0.05	0.06	0.02	—
MgO	1.56	0.27	0.96	2.32	1.10	0.29	Tr.
CaO	3.54	0.71	2.52	1.95	1.24	0.82	0.76
Na_2O	3.83	3.48	5.45	3.65	3.00	4.24	3.22
K_2O	3.04	5.06	5.78	3.02	6.00	4.49	5.94
TiO_2	0.57	0.20	0.58	0.76	0.60	0.25	0.25
P_2O_5	0.21	0.14	0.18	0.18	0.15	0.05	—
H_2O^+	—	—	—	1.33	0.69	0.62	0.65
H_2O^-	—	—	—	0.06	0.20	0.10	0.14
Total	99.87	99.84	99.76	99.03	99.55	99.53	100.16

1,2: High-Ca and low-Ca granites of Turekian and Wedepohl [1961].
3: Average syenite from Turekian and Wedepohl [1961].
4, 5, 6 & 7: Analyses of typical grey, Aswan, normal pink-red and strongly differentiated pink-red granites respectively as given by El Sokkary [1970].
*: Total iron is calculated as Fe_2O_3.

Table 3

CIPW norms of the investigated granitic rocks

Normative Mineral	Grey Granite 42	43	47	63	69	Aswan-Type Granite 159-A	232	244	Syenite 155
Ap	0.3	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Il	1.0	0.8	0.8	0.6	0.8	0.2	0.4	0.2	1.0
Or	17.0	12.5	22.5	21.5	11.5	37.0	25.0	30.5	27.0
Ab	59.5	46.5	40.0	58.5	57.5	35.0	38.0	32.0	40.5
An	3.2	20.0	6.0	—	4.5	1.7	6.5	9.2	9.5
Wo	3.5	1.4	5.0	7.2	3.0	2.7	1.6	—	1.0
Mt	1.5	1.9	5.1	1.6	2.1	1.2	2.4	—	0.9
Hm	—	—	—	—	—	—	0.2	—	—
En	2.6	11.8	2.8	2.6	3.0	1.8	2.0	1.0	1.4
Fs	4.0	3.5	0.2	1.9	2.8	2.8	—	1.2	4.6
C	—	—	—	—	—	—	—	0.7	—
Q	7.4	11.1	17.2	6.1	14.4	16.5	23.6	25.6	13.8

Table 4 shows the Niggli-values. Analyses are carried out according to the procedure described by El Sokkary [1970].

The grey granites of Gebel Oweinat show the chemical characteristics of typical high-Ca granites. They show decreasing trend in SiO_2 which ranges from 60.73—66.75% and rising trend in CaO with a range from 2.56—5.01%. The reference high-Ca granite of Turekian and Wedepohl [1961] has an average CaO content of

TABLE 3: Continued

Normative Mineral	Syenite 255	Pink-Red Granite 89	107	115	210	216	251	256	333
Ap	0.3	0.3	0.3	0.3	—	0.3	0.3	0.3	—
Il	0.4	0.4	0.2	0.2	0.2	0.2	0.4	0.4	0.4
Or	27.0	22.0	27.0	49.5	29.5	46.5	31.0	27.5	23.5
Ab	42.5	35.5	27.5	34.0	25.5	20.5	28.5	38.0	29.0
An	—	8.5	7.5	1.0	10.0	4.6	2.0	5.5	2.7
Wo	2.2	—	—	1.8	—	1.3	—	—	0.3
Mt	0.6	0.3	0.3	0.9	—	0.3	2.2	0.7	0.3
Hm	0.5	0.8	0.7	—	—	0.4	—	—	1.1
En	2.0	1.4	3.4	0.6	1.2	0.6	1.4	1.4	0.6
Fs	—	—	—	—	1.0	—	1.1	0.7	—
C	—	—	1.2	±	0.6	—	2.0	0.5	—
Ac	16.0	—	—	—	—	—	—	—	—
Q	8.5	30.8	32.2	21.8	32.0	25.2	30.9	25.0	42.0

TABLE 4

Niggli values of the investigated granitic rocks

NIGGLI value	Grey Granite 42	43	47	63	69	Aswan-Type Granite 159-A	232	244	Syenite 155
si	251	198	247	254	273	318	330	391	276
al	34.9	30.9	30.1	33.5	24.4	37.7	38.0	47.0	38.6
fm	22.2	34.8	28.7	16.4	23.8	16.8	18.9	6.6	19.4
c	10.8	1ü4	16.0	16.2	11.3	9.5	11.4	10.5	11.6
al	32.1	17.0	25.2	34.0	30.5	36.0	31.7	35.9	30.3
mg	0.24	0.59	0.20	0.33	0.28	0.20	0.26	0.45	0.16
k	0.22	0.25	0.36	0.27	0.17	0.52	0.40	0.49	0.40
ti	2.1	1.4	1.6	1.4	2.0	0.6	0.8	0.6	2.3
p	0.2	0.4	0.2	0.2	0.2	0.3	0.3	0.0	0.2

TABLE 4: Continued

NIGGLI value	Syenite 255	Pink-Red Granite 89	107	115	210	216	251	256	333
si	257	404	401	386	424	399	389	381	550
al	29.6	43.2	43.4	43.2	47.3	44.5	41.6	44.6	42.4
fm	26.7	12.0	15.8	7.5	7.2	6.7	21.1	11.1	14.0
c	5.5	11.3	9.5	7.5	12.3	9.7	3.6	7.3	5.1
alk	38.1	33.6	31.5	41.9	33.2	39.1	33.8	36.9	38.6
mg	0.15	0.33	0.63	0.26	0.48	0.30	0.18	0.34	0.18
k	0.30	0.39	0.49	0.67	0.54	0.69	0.52	0.42	0.45
ti	1.0	1.0	0.3	0.6	0.3	0.3	1.3	1.3	1.3
p	0.2	0.3	0.3	0.3	0.0	0.3	0.3	0.3	0.0

3.54% which fits well the range for the studied grey granites. The latter rocks show as well rising trends in total Fe_2O_3, MgO, Na_2O and TiO_2 while K_2O tends to drop.

On comparing the analyses of the Oweinat grey granites with that of the typical grey granite from the basement rocks of Egypt, there appears close similarity between the two sets of data particularly evident from the contents of SiO_2, FeO, MgO, CaO, K_2O and TiO_2, while Na_2O content is notably enriched in the Oweinat rocks. Therefore the Oweinat grey granites are high-Ca granites and are similar to the grey granites of the basement rocks of Egypt as developed in the Eastern Desert and Sinai peninsula.

The group of rocks with sample numbers 159-A, 232 and 244 has analyses which are intermediate between the reference low-Ca and high-Ca granites. This is clear from the contents of SiO_2, MgO, CaO while K_2O keeps a high level like the reference low-Ca granite. These are precisely the chemical characteristics of Aswan coarse granites as explained by EL SOKKARY [1970]. The CaO values for this group of rocks as given in Table 1 range from 1.82—2.25% which are intermediate when compared with the corresponding values of 0.71% and 3.54% for the low and high-Ca granites respectively.

Comparison of the analyses of samples 159-A, 232 and 244 with that of Aswan coarse granite as given in Table 2 reveals strong similarity between the two rocks exempting TiO_2 content which tends to drop in the studied group of rocks. This establishes the latter rocks as varieties of Aswan granite and will be termed hereafter Aswan-type granites. This is the first time to prove the occurrence of this granite type *i.e.* Aswan granites in the south Western Desert of Egypt.

Pink-red or younger granites have the chemical characteristics of low-Ca granites. This is particularly clear from the contents of SiO_2, total Fe_2O_3, MgO, CaO, Na_2O and K_2O which are close to corresponding values of the reference low-Ca granite. The pink-red granites are marked by enrichment trends in both SiO_2 and K_2O with simultaneous decreasing trends in total Fe_2O_3, MgO and CaO. Samples 115 and 216 show abnormally high contents of K_2O which amount to 8.19% and 7.57% K_2O, respectively. This is because the pink granite sample 115 develops more feldspars and less quartz than usual i.e. it represents relative inhomogenity in the distribution of these two minerals. Sample 216 contains some muscovite as the ferromagnesian mineral. It appears that sample 107 is somewhat enriched in biotite in order to account for the rising MgO content which equals 1.19% for this sample.

On comparing the analyses of the present pink granites with corresponding values of the normal pink-red granite as given by EL SOKKARY [1970], it is revealed that the former rocks are similar to the reference normal pink-red granite particularly from the point of view of the elements: SiO_2, Al_2O_3, total Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O and TiO_2. The red granite sample 333 reveals more similarity with the strongly differentiated pink-red granite especially clear from the high content of SiO_2 (77.87%) and the low value of CaO (0.65%). However, this point will be substantiated later on the basis of trace elements.

Thus the south Western Desert collection of pink-red granites are low-Ca granites. Most of them are similar to the normal variety of pink-red granites of the basement rocks of Egypt as developed in the Eastern Desert and Sinai peninsula. Rare members of the south Western Desert collection belong to the strongly fractionated granite variety.

Analytical data of sample 155 are very close to corresponding values of the reference syenite as given by TUREKIAN and WEDEPOHL [1961]. This parallelism becomes particularly evident from the contents of the elements: SiO_2, Al_2O_3, total

Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O and TiO_2. Sample 255 shows the chemical characteristics of femic syenite. This is because of marked deficiency in Al_2O_3 content (12.50%) and a simultaneous rise of total Fe_2O_3 (7.35%). Thus the two samples 155 and 255 represent two varieties of syenite.

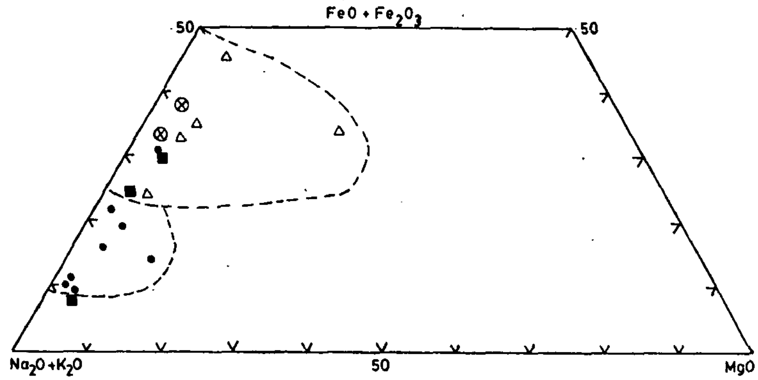

Fig. (4): The ternary relation (Na_2O+K_2O) - MgO - ($FeO+Fe_2O_3$) of the studied granitic rocks.
Symbols used: △ Grey Granite ■ Aswan-Type Granite
• Pink-Red Granite ⊗ Syenite

Fig. 4 is a ternary relation between $(Na_2O+K_2O)-MgO-(FeO+Fe_2O_3)$. It reveals that the grey granites are more enriched in total Fe_2O_3 and MgO with respect to the group of pink-red granites that tend to occupy the alkali end of the triangle. *Fig. 5* illustrates the ternary relation of the three normative minerals Or-Ab-An and shows that the studied grey granites are more enriched in Ab+An with respect to the pink-red granites that are located nearer to the Or field. *Fig. 6* is

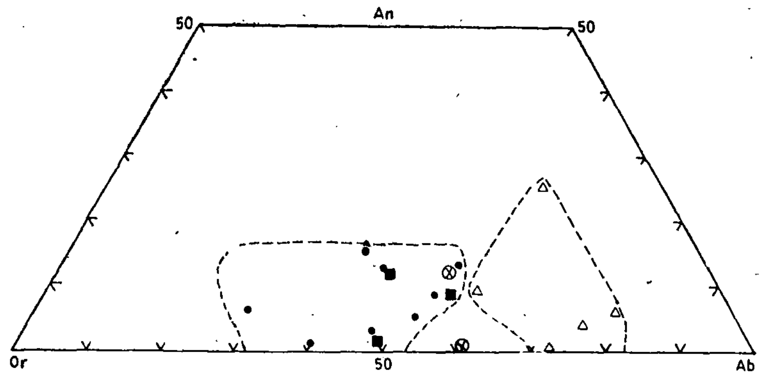

Fig. (5): The ternary relation Or - Ab - An of the studied granitic rocks.

a presentation of the ternary relation between the three NIGGLI values *c-alk-fm* and assures the fact that the Oweinat grey granites are more enriched in the *fm* and *c* components relative to the pink-red granites that tend to be enriched in the *alk* component. Moreover the pink-red granites show rising trends of their differentiation indices, felsic indices and mafic indices relative to the grey granites. Therefore the pink-red granites are in a more advanced state of differentiation relative to the grey granites and at least the two groups of granites may represent consanguineous rocks.

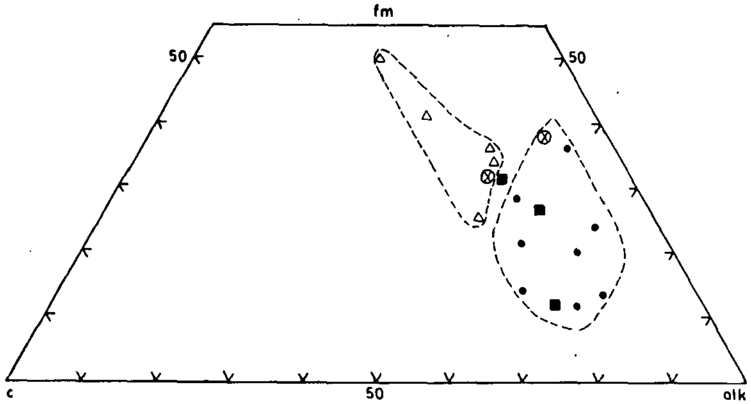

Fig.(6): Ternary diagram c - alk - fm of the studied granitic rocks.

GEOCHEMISTRY

Table 5 gives the trace elements data of the 18 investigated granites from the south Western Desert. The Table exposes the abundance values expressed in ppm of 13 trace elements: Ba, Rb, Sr, Y, Zr, Nb, La, Ce, Nd, Cr, Ni, Zn and Cu. Table 6 on the other hand reproduces the corresponding trace elements data of some reference rocks used for comparative purposes.

TABLE 5

Trace elements (ppm) of the investigated granitic rocks

Element	Grey Granite					Aswan-Type Granite			Syenite
	42	43	47	63	69	159-A	232	244	155
Ba	939	901	1359	1170	1054	1280	553	1172	2072
Rb	60	59	99	65	31	113	165	94	89
Sr	730	712	491	953	646	278	123	453	431
Y	12	9	15	8	7	30	23	3	38
Zr	158	151	205	179	144	199	193	95	626
Nb	8	7	12	4	6	18	25	8	36
La	30	27	24	38	19	17	2	3	63
Ce	59	46	41	53	42	57	28	15	123
Nd	28	22	22	26	15	46	8	5	77
Cr	96	110	42	49	72	19	17	16	19
Ni	56	64	27	38	61	12	12	14	11
Zn	76	74	59	59	75	58	54	29	95
Cu	33	30	18	31	75	12	17	21	15

TABLE 5: Continued

Element	Syenite	Pink-Red Granite							
	255	89	107	115	210	216	251	256	333
Ba	159	745	539	799	889	1264	906	1124	191
Rb	209	82	63	160	99	127	149	95	126
Sr	21	362	98	157	193	153	152	631	49
Y	35	5	8	5	4	6	90	13	60
Zr	784	280	72	16	121	22	398	153	1006
Nb	54	7	12	9	8	11	48	10	94
La	52	5	5	3	12	1	141	21	90
Ce	107	19	31	7	35	13	242	48	146
Nd	61	9	13	0	8	3	139	22	72
Cr	17	22	18	17	17	19	25	25	19
Ni	11	15	12	13	12	13	14	16	12
Zn	115	25	25	22	24	20	96	44	62
Cu	13	23	50	17	18	19	20	25	20

The Oweinat grey granites show trace elements distribution expected from high-Ca granitic rocks. The two elements Ba and Sr tend to show rising quantities in the Oweinat rocks. Ba has a range of 901—1359 ppm while Sr has a range of 491—953 ppm as compared with 420 and 440 ppm for these two elements respectively in the reference high-Ca granite.

Samples 159-A, 232 and 244 show that their trace elements distribution generally follows that of typical Aswan coarse granite as given in Table 6. These samples develop enrichment trends in Ba, Rb and Sr. Nevertheless the south Western Desert

TABLE 6

Trace elements (ppm) of some reference rocks

Element	High-Ca[1]	Low-Ca[2]	Syenite[3]	Grey[4]	Aswan[5]	Normal Pink-Red[6]	Strongly Diff.[7]
Ba	420	840	1600	635	1625	900	50
Rb	110	170	110	76	92	66	168
Sr	440	100	200	578	195	56	18
Y	35	40	20	6	24	22	23
Zr	140	175	500	234	235	137	75
Nb	20	21	35	—	—	—	—
La	45	55	70	4	248	6	4
Ce	—	—	161	—	—	—	—
Nd	—	—	56	—	—	—	—
Cr	23	4	2	80	0.4	1	1
Ni	15	5	4	4	2	1	1
Zn	60	39	130	—	—	—	—
Cu	30	10	5	8	8	8	5

1, 2: High-Ca and Low-Ca granites of TUREKIAN and WEDEPOHLT [1961].
3: Average syenite of TUREKIAN and WEDEPOHL [1961].
4, 5, 6, 7: Typical grey, Aswan, normal pink-red and strongly differentiated pink-red granites as given by EL SOKKARY [1970].

samples are impoverished in La together with Nd. The element La has a range from 2—17 ppm in the studied samples as compared with 248 ppm in the reference Aswan coarse granite.

The pink-red granites of the south Western Desert of Egypt show Ba, Rb and Sr contents which are in general similar to corresponding values of the reference low-Ca granite. Certain specimens with numbers 89, 210 and 256 have anomalously higher contents for their Sr. The gneissose granite sample 256 might be subjected to metasomatic processes in order to account for the high Sr content (631 ppm) of this sample. Other elements like Y, Nb, La, Ce and Nd tend to be depleted in the analysed rocks. This marks many members of the pink-red granites of the south Western Desert to be depleted in certain rare earth elements.

It seems that the porphyritic pink granite sample 251 is enriched in the rare earth elements Y, Zr, Nb, La, Ce and Nd possibly because of the presence of few grains of an accessory mineral which carries these rare earths. The red granite sample 333 has dropping Ba (191 ppm) and Sr (49 ppm) contents with rising Rb (126 ppm) which is in agreement with the contents of these elements in the strongly differentiated pink-red granite as given by El Sokkary (1970). The same sample tends to show enrichment trends in Y, Zr, Nb, La, Ce and Nd. Thus the mentioned red granite is classified here with the strongly fractionated rocks.

The trace elements contents of the syenite sample 155 are close to those of the average syenite of TUREKIAN and WEDEPOHL [1961], exempting Sr which is almost doubled in the analysed sample. On the other hand, the trace elements data of sample 255 reveal general parallelism with those of the reference syenite except a sharp drop in Ba (159 ppm) and Sr (21 ppm) with an increase in Rb (209 ppm). The reference syenite has its Ba content equals 1600 ppm, Sr 200 ppm and Rb 110 ppm. Zr is enriched as well in the analysed femic syenite (784 ppm) as compared with 500 ppm Zr in the reference syenite. The unusual distribution of Ba, Rb, Sr and Zr in sample 255 may be due to the presence of an abundance of an alkali amphibole in this sample.

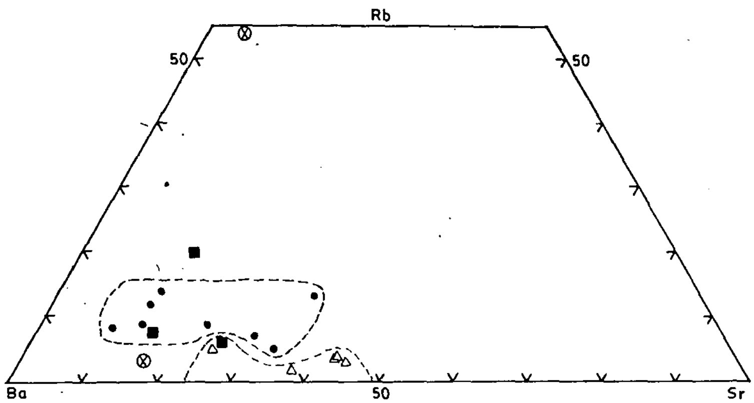

Fig.(7): The ternary relation Rb-Ba-Sr of the studied granitic rocks.

Fig. 7 is a diagramatic representation of the ternary relation of the three trace elements Ba, Sr and Rb. This relation is already used by EL BOUSEILY and EL SOKKARY [1975] in tracing differentiation trends in acidic suites. The diagram shows that the grey granites are located in a field that is rich in Ba and Sr but being poor in Rb, while the pink-red granites tend to occupy a field more enriched in Rb. This means that the pink-red granites are collectively in a more advanced state of differentiation relative to the grey granites and that the two groups are consanguineous. *Fig. 8* represents another ternary relation between the elements Ti/10-Zr-Y.

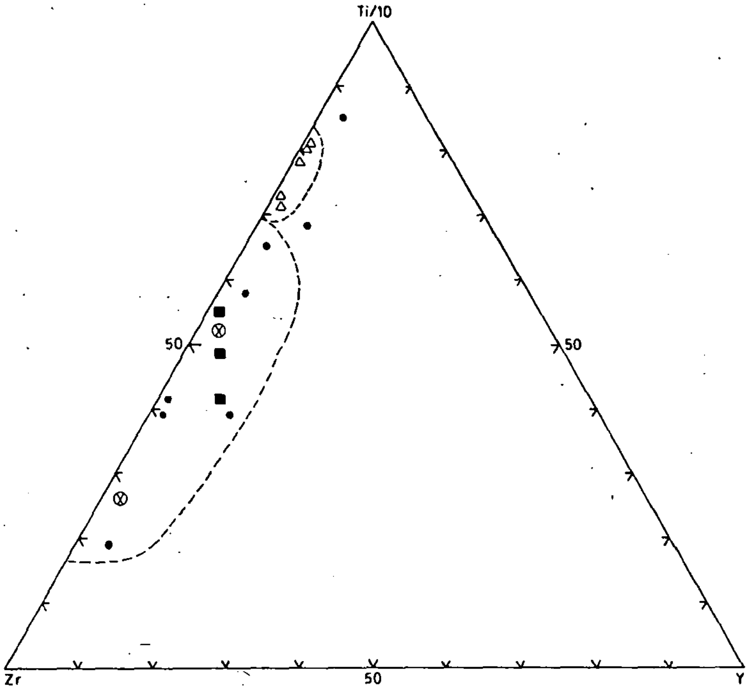

Fig.(8): Ternary diagrm Ti/10-Zr-Y of the studied granitic rocks.

It clarifies that the Oweinat grey granites occupy a position nearer to the Ti apex while the pink-red group is located somewhat away from that apex. A differentiation trend is then postulated between the two rock groups. These two diagrams assure that at least the grey granites and the pink-red granites are consanguineous rocks.

DISCUSSION

The present petrochemical and geochemical studies on the acidic igneous rocks from the south Western Desert of Egypt shed some light on the nature of these rocks. Admittedly such igneous rocks include the following types: grey granites, Aswan-type granites, normal pink-red granites, strongly differentiated pink-red granites and syenites. These rock units are the same like those in the basement rocks of the Eastern Desert and Sinai peninsula. Thus the basement rocks outcropping in the Eastern Desert and Sinai peninsula are extended across the Nile, though mostly subsurface, in the southern parts of the Western Desert. It is shown that at least both the grey granites and the pink-red granites are consanguineous rocks.

With respect to Aswan-type granites, this is the first time to prove their occurrence in the south Western Desert of Egypt. Thus Aswan granites are extended far west across the Nile (at Abu Simbil) till the area of Gebel Siri at longitude 31° E. These new occurrences make Aswan plutonites of much wider aereal distribution then previously known. Because of their peculiar chemical composition, Aswan plutonites can be grouped in a separate plutonic cycle.

From a tectonic point of view, all the above mentioned igneous rocks particularly the granite masses occurring in the south Western Desert are uplifted along dominant E—W fault system. This system is not the original deep seated system along which the granites were emplaced, but is a later system developed as a result of the gradual uplift of the southern parts of the Western Desert which caused the retreat of the Cretaceous Tethys. This situation is to be compared with the granitic groups occurring in the Eastern Desert and Sinai peninsula where each of them has its own geochemical and structural characteristics that make it distinguishable from others [El Sokkary and Salloum, 1974].

REFERENCES

Ball, J. [1902]: On the topographical and geological results of a reconnaissance survey of Gebe Garra and the oasis of Kurkur. Egyptian Survey Dept., Cairo.

Beadnell, H. J. L. [1909]: The relations of the Nubian sandstone and the crystalline rocks south of the oasis of Kharga. Q.J.G.S., London, Vol. *LXV*, p. 41—45.

El Bouseily, A. M. and El Sokkary, A. A. [1975]: The relation between Rb, Ba and Sr in granitic rocks. Chemical Geology, Vol. *16*, p. 207—219.

El Sokkary, A. A. [1970]: Geochemical studies of some granites in Egypt (U.A.R.). Ph. D. Thesis. Alexandria Univ.

El Sokkary, A. A. and Salloum, G. M. [1974]: The relation between the geochemistry and deep-seated faults of acid plutonites of Egypt. Acta Mineral.—Petr., Szeged, Vol. *XXI/2*, p. 183—190.

Geofizika [1966]: Final report on south Kharga and Tushka area, New Valley project. Vol. *1*, Cairo.

Hume, W. F. [1908]: The South Western Desert of Egypt. Cairo Scientific Jour., p. 279—286 and 314—325.

Issawi, B. [1968]: The geology of Kurkur-Dungel area. Geol. Survey of Egypt, Cairo, paper 46.

Lyons, A. G. [1894]: On the stratigraphy and physiography of the Libyan Desert of Egypt. Q.J.G.S., London, Vol. *50*, p. 531—547.

Turekian, K. K. and Wedepohl, K. H. [1961]: Distribution of the elements in some major units of the earth's crust. Geol. Soc. Am. Bull., Vol. *72*, p. 175—192.

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FRAMBOIDAL MANGANESE ORES OF ADILABAD, A. P., INDIA

J. S. R. KRISHNA RAO and B. VENKATA NAIDU

The manganese ore deposits of India occurring in crystalline complex were subjected to structural and mineralogical transforms since their formation with the result the original fabric and composition has changed considerable. Therefore, the study of structures, textures of manganese ores in less distorted and little metamorphosed terrains would be interesting in tracing the origin. During a study of polished sections of manganese ores from Adilabad District, Andhra Pradesh, some interesting forms in manganese ores are observed and considered as framboids. The framboids are described in this communication and illustrated with photos.

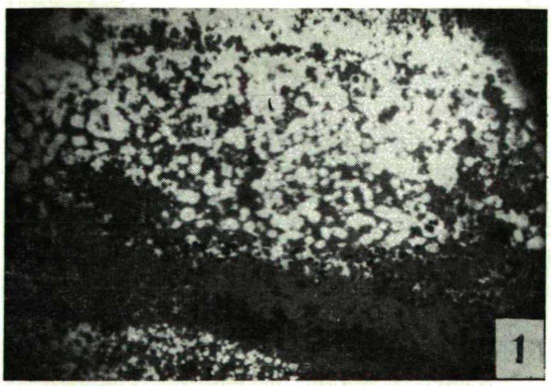

Fig. 1. The framboidal manganese oxide (white), and jasper (grey) in alternating layers. Magnification 70X.

The manganese ores located near Pipparagunta—Gotkur villages (long. 19° 32′ and lat. 78° 46′ and 47′, toposheet No. 56 I/5), Adilabad District, Andhra Pradesh were mined by Aditya Minerals Private Limited. The manganese ore is hard, compact and massive. The gangue material is siliceous. The gangue and the ore are in alternate layers of a few mm in thickness. The manganese ore mineral is pyrolusite. It is cream white in colour. Pleochroism is present particularly in oil and anisotropic under crossed nicols. Reflectivity is high. Pyrolusite is the mineral in framboidal form. The various framboids come together forming clusters or colonies; the margins are entire. The framboids are differing in their diameter as

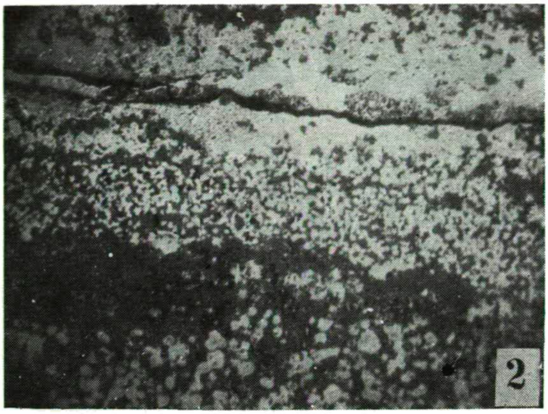

Fig. 2. The framboidal manganese oxide (white and grey) is fine grained. Various framboids coalesc ing and forming patches. Magnification 70X.

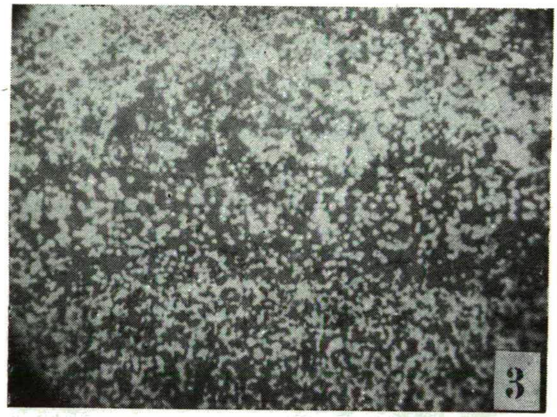

Fig. 3. Clustering of framboids in jasper bands. The jasper (grey) forms the background for the manganese framboids. Magnification 70X.

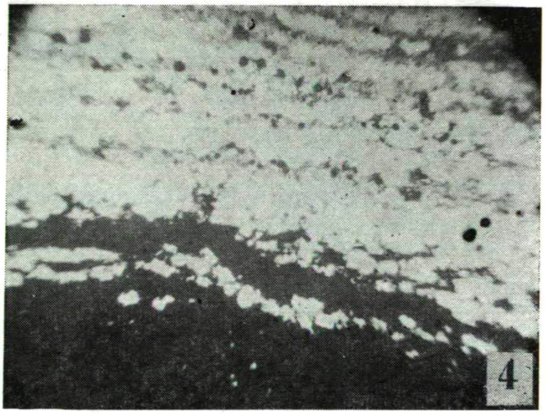

Fig. 4. A thin section showing manganese oxide (black) and jasper bands (white). Magnification 78X.

also in their lateral spread. They alternate with jasper bands which are continuous. Sometimes the manganese framboids are found to a lesser extent in jasper bands also *(Figs. 1* to *4)*. The framboidal forms (*Figs. 5* and *6*) are presented for ready comparison [AMSTUTZ, G. C. and BERNARD, A. J., 1971].

BASTIN [1950] suggested that SCHNEIDERHÖHN interpreted the small chalcopyrite spherules as replacing colonies of sulphur depositing bacteria and the tiny grains of which they were composed as "fossil bacteria". He suggested that the various sizes and the form of the spherules is in support of bacterial hypothesis. According to RAMDOHR [1969] the so called framboids are colloform bodies; however, he agreed that the smallest units observed by him are represented by minute spherical bodies having the dimensions of certain microorganisms. So, he suggested a bacterial origin for their precipitation. JOHN L. MERO [1969] described recent manganese ores as due to biological activity.

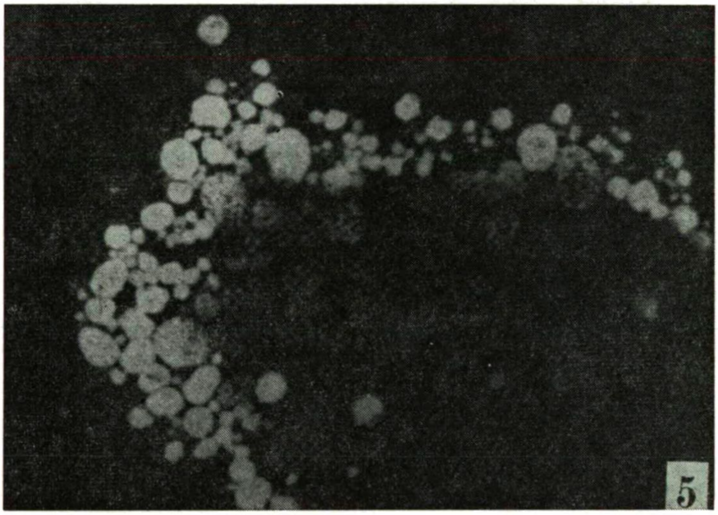

Fig. 5. Microphotograph of polished section in heavy mineral concentrate from dredged sample M_6, showing goethite pseudomorphs after framboidal pyrite; white framboids are pyrite, grey framboids are goethite. Magnification 400X.

RUST [1935] believed the framboids are probably metacolloids, crystallisation starting simultaneously at many points. It may be like bunching of tiny pyrite grains floating in chalcopyrite gel.

The manganese ores under investigation are of uniform composition. The size and shape are more or less uniform. There are no pore spaces or tension cracks or cavities or any gel structures. Further the rock formations in which they are found are of Penganga age consisting of shales, limestones, slates with pyrite, organic matter (0.315 to 1.96%) and fossil tracks. Recently BHAGABATI SARKAR [1974] reported various types of algal stromatolites, trace fossils (burrows) and some microfossils including filamentous structures and a variety of isolated and clustered spheroids of probable algal or fungal affinities and some doubtful microfossils from the limestones of Madhya Pradesh, India. Thus, primitive life is indicated in and around the manganese ores under investigation. It is therefore considered possible that the primary manganese deposition at least in part may be due to bacterial activity.

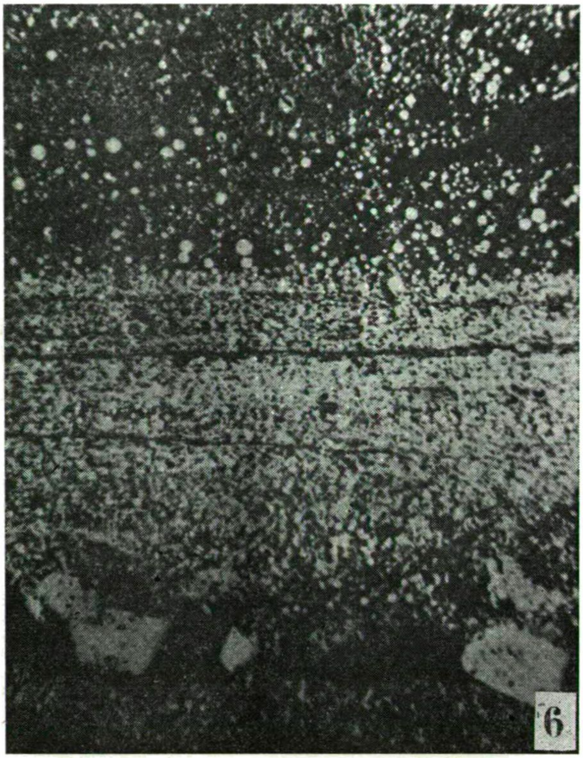

Fig. 6. Deposit Tekeli, Kazakhstan.
Pyrite ore with globules (above) thin layered (centre) and porphyroblastic (below). Magnification 40X.

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REFERENCES

BHAGABATI SARKAR [1974]: Biogenic sedimentary structures and microfossils of the Bhander limestones (Proterozoic), India. Geol. Min. & Met. Soc. of India, 1974, p. 143—156.

EDSON S. BASTIN [1950]: Interpretation of Ore textures — text book. pp. 30—31.

HONNOREZ, J., HONNOREZ, B.-GUERSTEIN, VALETTE. J. and WAUSCHKUHN, A. [1976]: Present day formation of an exhalative sulphide deposit at volcano (Thyrrhenian Sea), Part II: Active crystallisation of Fumarolic Sulphides in the volcanic sediments of the Baia di Levante. Text book — Ores in Sediments. G. C. Amstutz and A. J. Bernard (1971) p. 139—166.

JOHN L. MERO [1969]: text book — The mineral resources of the Sea. pp. 149.
PAUL RAMDOHR [1969]: text book — The ore minerals and their intergrowths. p. 784—788.
SCHADLUN, T. N. [1971]: On the origin of "Kies" ore and Pb-Zn deposits in sediments. Text book- Ores in Sediments, Amstutz, G. C. and Bernard, A. J., (1971), p. 272.
SHATSKIY, N. S. translated by SOKOLOFF, V. P. [1964]: On manganiferous formations and the metallogeny of manganese, Paper I. Volcanogenic-Sedimentary mangani-ferous formatio ns. Jour Int. Geol. Rev., Vol. 6, p. 1030—1056.

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LATEST PLEISTOCENE GEOHISTORY OF THE BÁCSKA LOESS AREA

B. MOLNÁR and E. KROLOPP

INTRODUCTION

The Bácska Loess Area is situated in the southern part of the Danube-Tisza Interfluve. A smaller part of it is shared by Hungary, the greater part by Yugoslavia *(Fig. 1)*.

The early Danube flowed still diagonally, in southwest direction across what is now the Danube-Tisza Interfluve, probably up to the Günz-Mindel interglacial. Thereafter it got into its present-day meridional valley. After the Günz-Mindel interglacial the Danube-Tisza Interfluve was abandoned by fluvial accumulation so that only eolian sediments, loesses and wind-blown sands could settle down on its

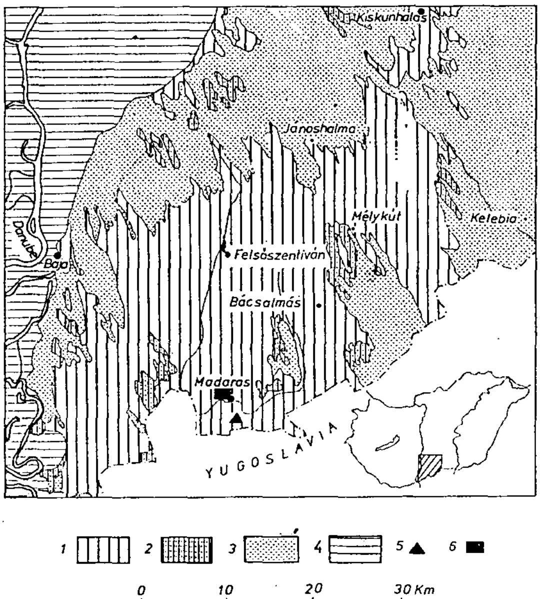


Fig. 1. Geological map of the Hungarian share of the Bácska Loess Area and of its surroundings 1. Typical loess, 2. Sandy loess, 3. Wind-blown sand, 4. Alluvium, 5. Site of the Madaras section, 6. Location of the large-scale geological map showing the *Katymár-Madaras* area (area shown in *Fig. 6.*)

surface. As a result of this, tens of metres, and in several places even more than a hundred m, of alternating wind-blown sand and loess can now be found in this area. In the northern part of the Bácska Loess Area, at Felsőszentiván, the eolian sediments attain 120 m in thickness. Farther south their thickness rapidly decreases, to become as little as 60 m in the vicinity of Madaras [I. MIHÁLTZ, 1953, B. MOLNÁR, 1961, 1970, 1973, 1975, E. KROLOPP, 1970, M. KRETZOI—E. KROLOPP, 1972].

The surface of the Danube-Tisza Interfluve is covered today predominantly by wind-blown sands, a minor part being shared by loess. Out of the loess-covered parts, the Bácska Loess Area is the largest and most important. The Hungarian share of the study area lies SSE of the Baja—Jánoshalma—Kiskunhalas line, reaching almost as far east as the Budapest—Kelebia (Belgrade) railway line. In southern direction it continues beyond the frontier, in Yugoslavia, being bounded by the Danube valley in the west. In the north and east, it borders on wind-blown sands, in the west it is flanked by the Danube's alluvial plain varying between 80 and 90 m in altitude. On the northern border there are the wind-blown sands of Illancs with their topmost point of 174 m altitude, representing, at the same time, the highest point of the Danube-Tisza Interfluve. The wind-blown sands to the east of the loess area have an altitude of 110 to 120 m a.s.l. The surface of the study area has an altitude of 130 m in the northwest and 120 m near the Hungarian—Yugoslav frontier.

The Hungarian part of the Bácska loess is characterized by low relative relief (weak relief energy), though the two channels of the Kigyós rivulet have heavily incised into the loess surface and thus have markedly furrowed the level loess surface. The geomorphological pattern is further complicated by the occurrence of loess-buried wind-blown sand bars of northwest-southeast direction, soaring remarkably above their level loess background.

The Hungarian share of the loess area lies close to the Hungarian—Yugoslavian border, thus its detailed geological investigation was delayed for a long time, despite the fact that, on account of the renewed large-scale geological mapping projects, both Hungary and Yugoslavia did feel an urgent need for an exact knowledge of the geological makeup of the study area and for the clarification of its latest Pleistocene geohistory. Notably, the fact is that a key to understanding the geology of the whole area is in its Hungarian part. The contact of both the wind-blown sands and the loesses of the Danube-Tisza Interfluve and their superposition can be studied best here. This question is discussed in the present paper and it is sought to fill the gap of knowledge still existing in this respect.

During our previous traverses we observed the occurrence of a great many of well-exposed geological sections in the Bácska Loess Area. Of these the exposures of Madaras and Katymár proved to be the best. The gastropod-rich loess covering the surface is exposed, together with the wind-blown sands underneath, at both localities.

At Madaras the loess is mined for brick (*Fig. 1,* Picture 1). In 1966, while extracting the raw material, the miners discovered a culture layer 170 to 180 cm above the floor of the mine pit, at about 8 m depth under the surface. Undertaking excavations to salvage the artifacts, V. T. DOBOSI unearthed a surface of 15.3 m^2 on which she found three fireplace spots. The fireplaces were covered by a thick ash and charcoal layer. The artifacts recovered included 33 flint implements, 188 flint splinters and an object identified, with some reserve though, as a bone implement. On the basis of the studied implements, V. T. DOBOSI considers the Madaras site and another prehistoric campsite discovered earlier at Ságvár, to the south of Lake Balaton, to represent two approximately identical sites of the eastern-gravetti culture.

Only two of the poorly preserved bone fragments recovered from the culture layer could be identified (*Equus* sp., det. by D. JÁNOSSY). In the charcoal J. STIEBER identified the presence of *Betula, Pinus,* of the group of *Pinus silvestris* and of *Pinus cembra.* Only two of the 128 charcoal fragments examined were remnants of deciduous trees, the rest having been, all, conifers. From these data, J. STIEBER in-

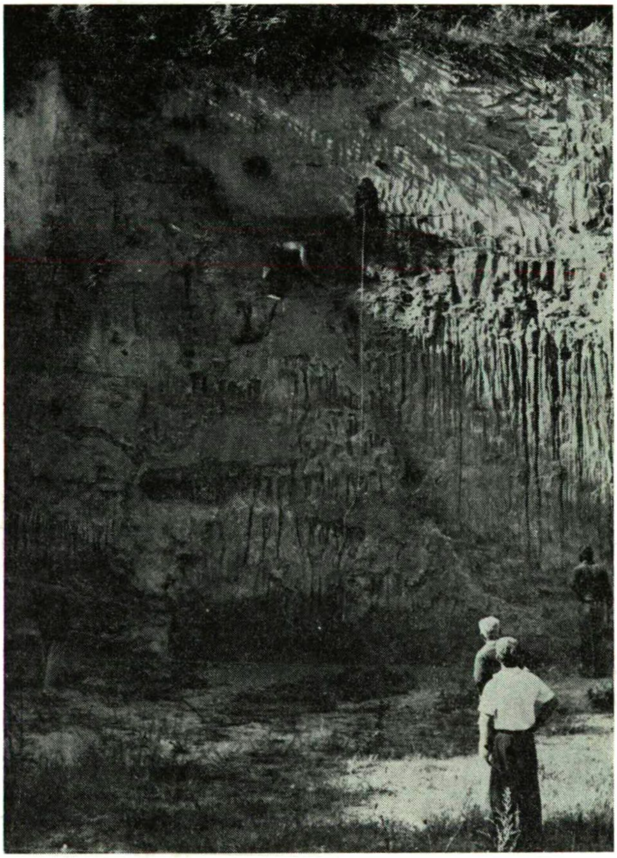
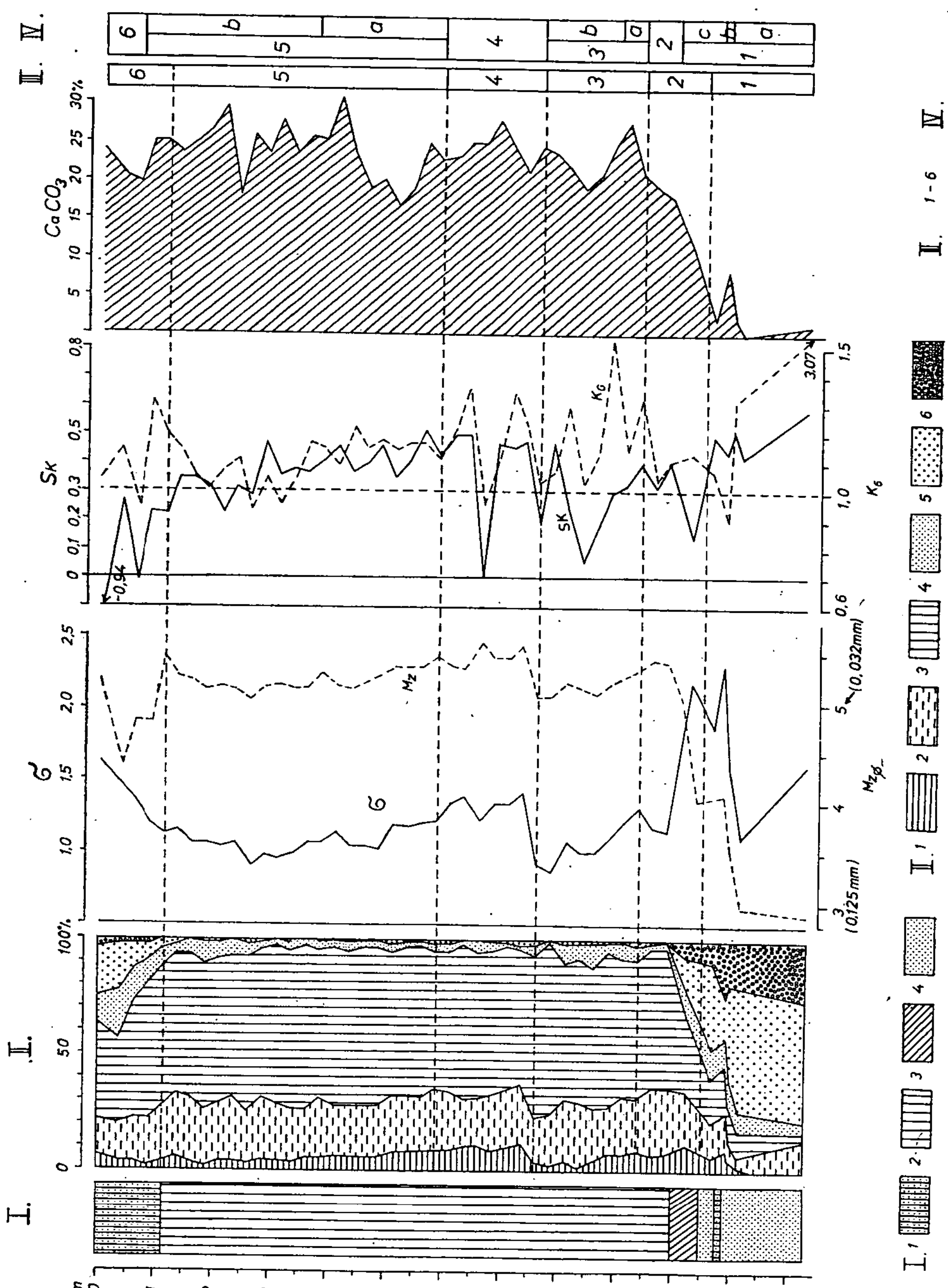


Fig. 2. The *Madaras* loess exposure

ferred mixed *Pinus cembra—Pinus silvestris* forests and an explicitely continental, cold climate [J. STIEBER, 1967]. The charcoal remnants were tested with the radioactive C^{14} method by M. A. GREY of the Niedersächsisches Landesamt für Bodenforschung, *Hannover,* FRG. He obtained for the site an absolute age of $18\,080 \pm 405$ years [V. T. DOBOSI, 1967a].

The miners had even earlier observed a bone-containing layer about 180 cm deeper than the 1966 mine pit floor and the examined culture layer, but no new result was yielded either by this layer, or by the horizon which V. T. DOBOSI dis-



I.
II.
III. IV.
$CaCO_3$
30%
Sk
K_G
-0,94
3.07
σ
Mz
$Mz\phi$
5 (0,032mm)
3 (0,125mm)
m
I. 1
2
3
4
5
6
II. 1
III. 1-6
IV.

covered some 70 cm above it and which contained some bones of poor preservation, locally totally dissolved, or by the few implements found in 1967. Only L. KORDOS did find in 1975, in the northern part of the exposure, in a horizon nearly identical with the already-known culture layer, two tooth plate fragments of a *Mammuthus* cf. *primigenius* BLUMENBACH and one metacarpus of an *Equus* sp., the proximal end of which was damaged. The size data of this latter find are the following: length ± 240 mm, distal width ± 55 mm, width of diaphysis 58 mm, height of diaphysis 27 mm. These remnants of a mammoth and of a horse of medium size are typical of the Mid-Würm glaciation.

In the light of the above results the Madaras section was selected for geological elaboration. The northern side of the Madaras brickyard has a hight of 9.8 m. This exposure was complemented with a trial pit of 1.5 m depth and a borehole of 1.0 m depth, so that a total of 12.3 m of geological section was studied and evaluated. While being studied, the section was visited by mapping geologists working on the Yugoslavian side of the frontier. Samples were taken at every 25 cm or at any change in lithology. They were then subjected to detailed sedimentological and paleontological analyses. The results can be reported as follows.

LITHOLOGICAL FEATURES OF THE MADARAS SECTION

46 samples were taken from the Madaras section. They were first macroscopically described, then analyzed hydrometrically (a method based on specific weight measurements) and by sieving. The results are shown by plotting techniques in *Fig. 3* (Columns I—II).

The section begins at its base with light yellow small sands. The share of the 0.1 to 0.2 mm sand fraction is more than 50%, that of the 0.2 to 0.5 mm one being more than 20—25%. This sand layer is overlain, between 10.8 and 10.9 m, by light yellow sandy loess with *Pseudomycelium* and, in the 10.5—10.8 m interval follow again small sands completely identical with the previous ones.

The sands are followed in the 10.0—10.5 m interval, by a brown humic, chernozem-like soil horizon developed on a loessy basis. From 1.25 m to 10.0 m there is typical loess of loose structure, a little even sandy, looking completely homogeneous to the naked eye. The loess fraction shares 60—70% in this interval. Of the coarser fractions, fine sand shares 3 to 7%, small sands 0.5 to 1.5%. Clays and fine silts are contained in 25 to 30%. The bulk of the section is constituted by loess attaining 8.73 m in thickness.

The topmost 0.0—1.25 m interval of the section is sandy loess. Within the loess the sand content increases continuously from the base to the top of the section, attaining its maximum, 44.0%, between 0.25 and 0.50 m.

Having read the necessary parameters from the cumulative curves of the laboratory analyses of the grain composition and then substituting the data into the formula proposed by D. L. IMAN, R. L. FOLK and W. C. WARD, the individual sedimentological statistical data were calculated. The results have been plotted as a function of depth *(Fig. 3)* [D. L. IMAN, 1952, R. L. FOLK and W. C. WARD, 1957].

Fig. 3. Sedimentological features of the Madaras section I. 1. Sandy loess, 2. Typical loess, 3. Loess-based, chernozem-like soil, 4. Small-grained wind-blown sand. II. 1. Clay (0.005 mm∅), 2. Fine silt (0.005—0.02 mm∅), 3. Loess fraction (0.02—0.06 mm∅), 4. Fine sand (0.06—0.1 mm∅), 5. Small sand (0.1—0.2 mm∅), 6. Medium sand (0.2—0.5 mm∅), III. Intervals distinguished on the basis of sedimentological studies. IV. Intervals distinguished on the basis of paleontological studies.

Medium grain size (Mz) expresses the mean value of the grain composition of the sediment. Its calculation is done as follows:

$$Mz = \frac{\varphi_{16} + \varphi_{50} + \varphi_{84}}{3}$$

Mz is one of the expressions of the mean trend of grain size distribution and its value is proportional with the kinetic energy of the depositing medium (sedimentary environment).

In the Madaras section the mean grain size varies between 2.89 and 5.63φ, *i.e.* from 0.38 to 0.022 mm. Least fluctuation occurs in the 1.25—10.0 m interval; notably, here the mean grain size is as low as 5.00—5.63φ, *i.e.* between 0.03 and 0.02 mm.

Consequently, at the time of deposition of the sediment the kinetic energy of the depositing medium was very well-balanced. Greatest changes in mean grain size are found there, where a material coarser than the loess, *i.e.* sand, also occurs, or there, where sedimentation was followed by transformation processes such as soil genesis. In other words, they are found in the basal and the topmost parts of the section.

The degree of sorting of the sediment, dispersion (σ), is calculated by using the following formula:

$$\sigma = \frac{\varphi_{84} - \varphi_{16}}{4} + \frac{\varphi_{95} - \varphi_{5}}{6.6}$$

σ means the deviation from the average of the kinetic energy of the sedimentary environment. The longer the value of the transportation energy remains unchanged, the better the sediment is sorted.

In the Madaras section this value is 0.87 to 2.31, *i.e.* the sediment varies between poorly and moderately sorted *(Fig. 3)*. In the lower part of the section, where sand and loess alternate, and where soil-generating processes were also involved in the postgenetic transformation of the sediment, the sorting is worse. Here the value of σ is between 1.56 and 2.31. In the 1.25—10.0 m interval it is rather stable, around 10.0—1.3, to show again an increase farther up the section.

It is interesting to compare the behaviour of the curves of Mz and σ. In the lower part of the section, from 9.25 downwards, the increase of the grain size is usually accompanied by worse sorting. In the 7.75—9.25 m interval, the loess, looking macroscopically somewhat more compact, is more moderately sorted. The two curves showing the variation of the grain size and sorting run almost parallel. In 6.0—7.75 m the grain size increases, while the sorting declines. In 1.25—6.0 m the contrary is the case, *i.e.* the grain size decreases, the sorting improves, but the curve remains invariably parallel. Between 0.0 and 1.25 m, however, again a decrease in sorting is associated with the increase of the grain size. Consequently, the two curves in this interval are not parallel, but largely convergent.

Skewness (Sk) expresses the asymmetry of the curve. Its direction is measured as related to the median. Its value is calculated as follows:

$$Sk = \frac{1}{2}\left(\frac{\varphi_{84} + \varphi_{12} 2\varphi_{50}}{\varphi_{84} - \varphi_{16}} + \frac{\varphi_{95} + \varphi_{5} - 2\varphi_{50}}{\varphi_{95} - \varphi_{5}}\right)$$

A negative value of skewness, *i.e.* a curve skewed towards coarser fractions, has the meaning that the kinetic energy of the sedimentary environment was for a long time higher than the average kinetic energy. A positive value of skewness means a curve skewed towards the fine fractions, in other words, that the energy of the sedimentary environment must have been for a long time (or more frequently) less than the average.

In the Madaras section the skewness varies between -0.94 and $+0.59$ as extreme values. Looking at the plot of *Fig. 3*, one can readily see that the *Sk* curve is in most cases shifted towards positive skewness. In only two near-surface samples does it overstep, in a negative sense, the point 0 corresponding to a completely symmetrical curve, just touching it at 6.5 m.

In the lower half of the section, in the 6.5—12.3 m interval, the skewness heavily oscillates with values within the 0.01—0.59 range. This means that the energy of the depositing medium was more often and with some fluctuation less than the average kinetic energy.

Between 1.25 and 6.5 m the skewness is very stable, showing a slow upward decrease with values of 0.22 to 0.50. Thus the kinetic energy of the sedimentary environment must have been less than the average for an abnormally long time, though with smaller oscillations compared to the preceding interval.

Finally, in the 0.0—1.25 m interval the sediment yields curves bearing witness to a subsymmetrical grain composition so that again a curve stretch of higher oscillation can be observed on the plot concerned.

Curtosis (K_G) expresses how much a frequency curve is pointed. The relation of 90% of the sediment to the middle-range 50% is examined. Properly speaking, nothing else than the sorting ratio of the grain size distribution in the middle range of 50 to 90% is dealt with. Its value is calculated by the aid of the following formula:

$$K_G = \frac{\varphi_{95} - \varphi_5}{2.44(\varphi_{75} - \varphi_{25})}$$

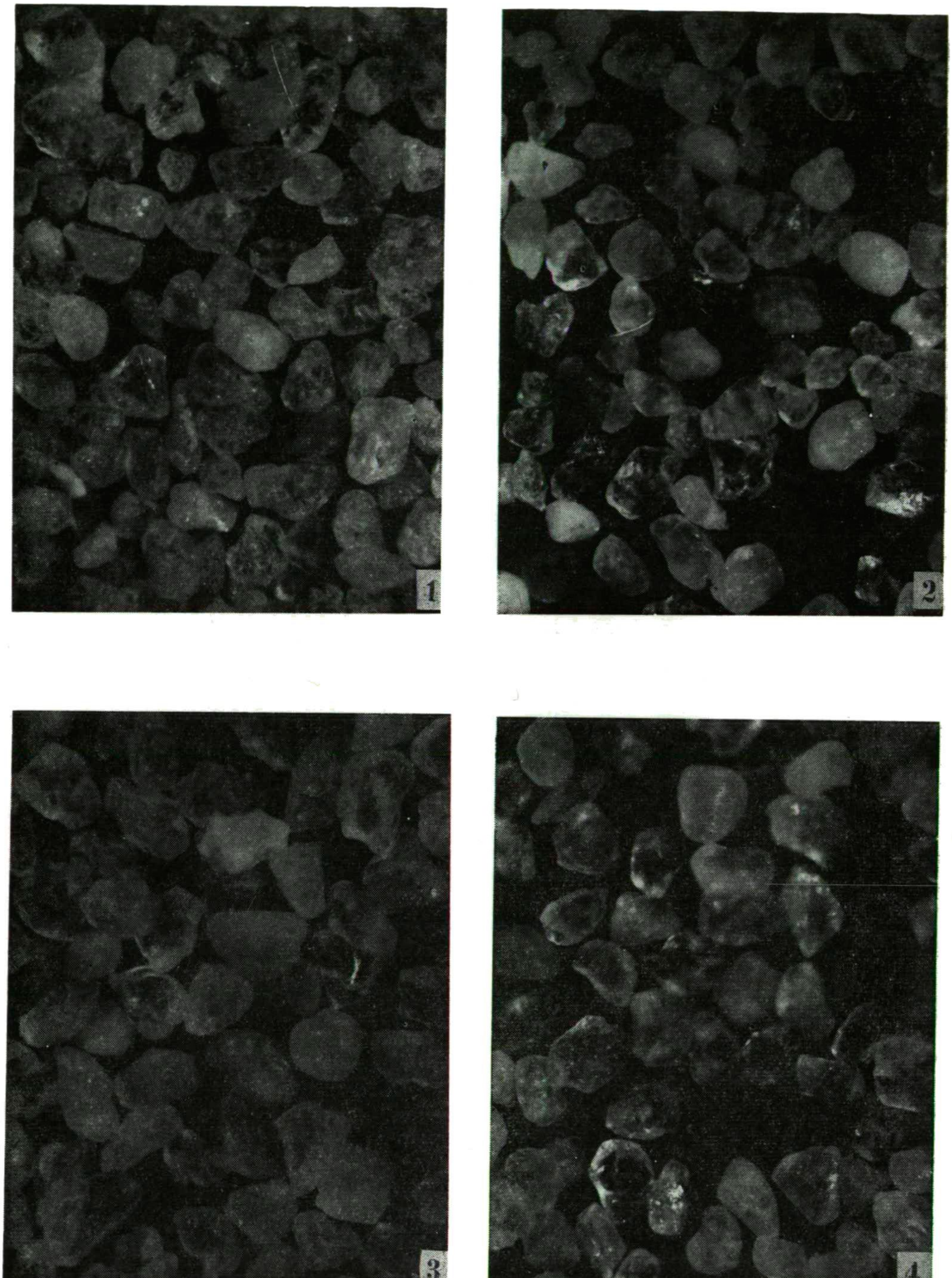
If the K_G value of the curve equals 1, the distribution is normal and the fluctuations of the kinetic energy of the sedimentary environment affected only sediments of a grain size corresponding to the 50% range of the curve. If the value of curtosis is greater than 1, the oscillations of the velocity did for a long time not exceed 50% of the average velocity.

In the Madaras section the values of curtosis are in the 0.90—3.07 range, but, of the striking value, 3.07, of the sample taken from the greatest depth be disregarded, so they prove to be as low as 0.90 to 1.53. In the majority of the cases the value of curtosis is greater than 1, which means that the amplitude of oscillations of the sedimentary environment at the time of sedimentation did for a long time not exceed 50% of the average velocity.

Comparing the curtosis and asymmetry curves of *Fig. 3*, one can see the major changes in the behaviour of the two curves to be subparallel, except for a few cases (e.g. at 1.0 or 9.0 m).

The collected samples were analyzed for calcium carbonate content by being treated in hydrochloric acid. The calcium carbonate content of the Madaras section varies between 0.0 and 31.0%. However, according to the values obtained, two substantially different vertical ranges can be distinguished. In the 10.0—12.3 m interval the calcium carbonate content is between 0.0 and 12.0%, in the 0.0—10.0 m interval it is substantially greater, ranging from 17.0 to 31.0%. The smaller carbonate content of the lower depth range is due to the occurrence here of a soil layer developed predominantly on sands and loesses. The carbonate that used to be in the soil and

PLATE I



the thin loess layer of the 10.8—10.9 m interval was lost to leaching, while the sands have, as a rule, a lower carbonate content compared to that of the loess. The 0.0—10.0 m interval shows high calcium carbonate values of 20 to 25% which are generally characteristic of the loesses of the Danube-Tisza Interfluve.

The shape of the quartz grains of the sands occurring in the lower part of the section and at a depth of 2 m under the surface in the same mine pit, 20 m north of the section under study, was examined by the CAILLEUX-method [A. CAILLEUX 1952]. The quartz grains of the sand dune outcropping from below the loess blanket 1 km west of the exposure were also examined. The results are summarized in Table 1. As can be seen, the rather fine, 0.1 to 0.2 mm, grains corresponding to

TABLE 1

Results of grain shape analyses obtained by the Cailleux method for 0.1 to 0.2 mm quartz grains from wind-blown sands interbedded with and underlying the loess at Madaras

Locality		Grain type		Photographs
		NU (%)	RM (%)	
The Madaras	10.9—11.0 m	19.0	81.0	Plate I, Fig. 1.
section	11.3—12.3 m	20.0	80.0	Plate I, Fig. 2—3
Sand lens lying at 2 m depth under the surface		14.0	86.0	Plate I, Fig. 5.
Sand outcropping from below the loess blanket at 1 km distance to the west from the exposure		14.0	86,0	

NU = Sharp-edged, splintery grains; RM = Rounded, mat grains.

the predominant sand fraction still consist, themselves, mainly of rounded grains of mat surface. The samples were also photographed under a stereomicroscope (Plate I, *Figs. 1—4*). On the photographs predominantly rounded grains can be seen. According to A. CAILLEUX, the above results and observations prove convincingly that both the sands underlying the loess and those interbedded with it, represent wind-blown sands.

These same samples were analyzed for heavy minerals as well. As proved by the results, the sands must have been blown out of the Danube valley by the winds, thus originating from a Danubian source area, a fact corroborated by the photographs made under the mineralogical microscope (Plate II, *Figs. 1—4*). It is pre-

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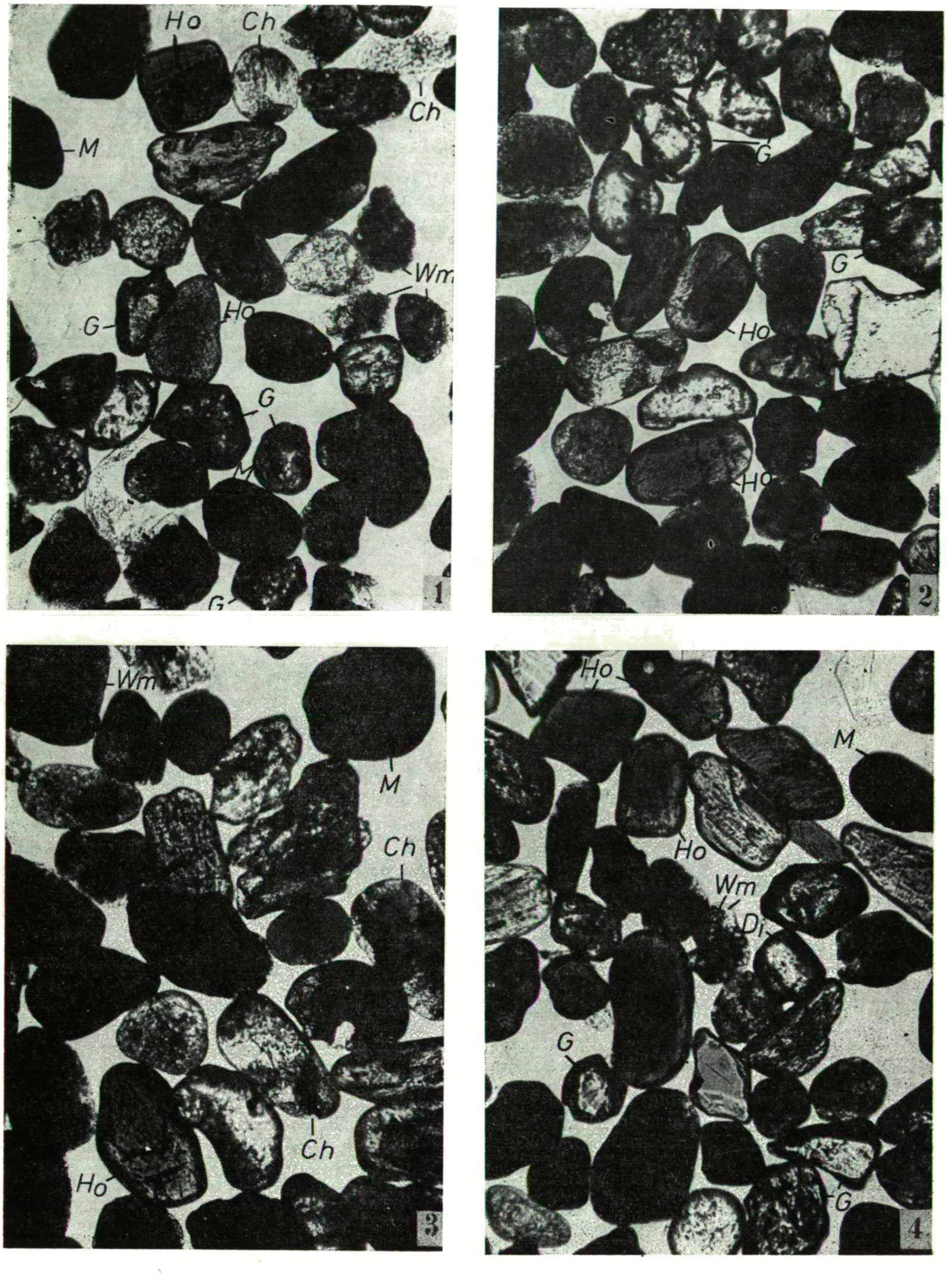
PLATE I

Stereomicroscopic images of 0.1 to 0.2 mm quartz grains from wind-blown sands interbedded with or underlying the loess at *Madaras*

1. The *Madaras* section: 10.9—11.0 m
2. The *Madaras* section: 11.3—12.3 m
3. The *Madaras* section: 11.3—12.3 m
4. Sand lens of the Madaras exposure


Ho
Ch
Ch
M
Wm
G
Ho
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M
G
1
G
G
Ho
Ho
2
Wm
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3
Ho
M
Ho
Wm
Di
G
G
4

dominantly garnets, well-rounded common hornblendes, magnetites and weathered minerals that are visible on the photographs. Each of these implies a Danubian origin [B. MOLNÁR 1961, 1964, 1966, 1970].

Having a look at *Fig. 3* summarizing the most important results, one can easily recognize, even in intervals seeming to be homogeneous to the unaided eye, that the 12.3 m section consists of several distinct parts differring from one another as far as the sedimentological features, *i.e.* the mechanism of accumulation, the changes in its energy and the postgenetic transformations of the material are concerned. The individual parts show up the following characteristics:

1. The 10.5—12.3 m interval comprises wind-blown sands and an interbedded, thin sandy loess layer. It is characterized by coarser grain size, poorer and rapidly changing sorting, a heavy positive asymmetry, a striking value of curtosis and a very low amount of calcium carbonate. All these indicate that the energy responsible for the deposition of the sediment must have been most diversified of all parts of the section. The observed sedimentological features reflect even otherwise shock-like changes in sedimentary energy. The interval can be further split up into an upper and a lower wind-blown sand and an interbedded sandy loess horizon.

2. The 9.25—10.5 m interval is characterized by a granulometric composition much finer than the former, by a rapidly improving sorting associated with the refinement of the grain size, by a positive skewness smaller than that of the previous interval, by a substantially smaller and more equilibrated curtosis as well as by a calcium carbonate content increasing from the base to the top of the sequence at a rapid rate. Thus the energetic conditions that were involved in the deposition of the sediment must have been much more steady than they were in the case of the previous interval. The interval under consideration can be split up into two additional parts. In the lower part there appears a loess-based chernozem-like soil suggestive of a warmer climate, while the upper part includes typical loesses the origin of which is indicative of a climate turning colder.

3. In the 7.75—9.25 m interval there is such a loess facies in which clay and fine silt decrease in quantity, while the fine sand content increases. The dynamics of the sedimentary environment must have been equilibrated, the sorting gradually improving from base to top. The values of the asymmetry and curtosis of the sediment, however, are markedly variable. Consequently, the sedimentation that took place in this interval must have evolved under the conditions of rather steady dynamics due to minor climatic changes. The sedimentation characteristics do not enable us to distinguish further subintervals within it.

4. Between 6.0 and 7.75 m, the quantity of clay and fine silt shows a sudden increase. Fine sand though decreasing in content, is characterized by an increasing

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PLATE II

Heavy minerals recovered from the 0.1 to 0.2 mm fraction of the wind-blown sands interbedded with and underlying the loess at Madaras. The pictures were photographed under mineralogical microscope, at parallel nicols, the minerals having been mounted in nitrobensene with an optical refringency of 1.552. Abbreviations of mineral names shown on the images: Di: Diopside, M: Magnetite, Ch: Chlorite, Ho: Hornblende, G: Garnet, W: Weathered mineral.

1. The Madaras section: 10.9—11.0 m
2. The Madaras section: 11.3—12.3 m
3. The Madaras section: 11.3—12.3 m
4. Sand lens of the Madaras exposure

mean energy of the sedimentary environment. The sorting of the sediment is weaker compared to that of the previous interval. Asymmetry and curtosis show invariably a wide range of variation, though the trend of this variation is unidirectional in both cases, as proved by the parallel run of the two corresponding curves in *Fig. 3*. Consequently, the energy responsible for sedimentation must have been a little greater, but somewhat more equilibrated and steady, on the average, than in the previous interval. The sedimentological features of the interval do not enable any further division.

5. The 1.25—6.0 m interval is characterized by a very steady and well-balanced average energy of deposition, by a good sorting, a rather considerable, though steady, positive skewness, a steady curtosis and a high carbonate percentage. It is this five-metre interval in all of the Madaras section that indicates the most steady sedimentation conditions. Notably, very steady, cold climatic conditions, typical of loess sedimentation, must have prevailed at the time of deposition. In the light of changes in asymmetry and curtosis the interval can be split up into two subintervals. Between 3.75 and 6.0 m, though markedly steady, both asymmetry and curtosis show a somewhat higher value than is the case with the 1.25—3.75 m subinterval.

6. In the 0.0—1.25 m interval the sand content of the loess increases rapidly and the average energy of sedimentation also increases. The value of this second characteristic feature, however, showed a less rapid change, as manifested by sorting, asymmetry and curtosis alike. In *Fig. 3* all the curves of sedimentological features pertaining to this interval show unsteady variations with rapid changes and striking differences in the sedimentary conditions they reflect.

PALEONTOLOGICAL RESULTS OBTAINED FOR THE MADARAS SECTION

Sedimentological analyses were coupled with parallel paleontological studies on the material of the same samples. About 4 kg of sediment per sample was washed through a 0.8 mm mesh sieve on the location. The paleontological material consisted, irrespective of a very small number of vertebrate remains and charcoal remnants, predominantly of mollusc shells. Since the sediment was washed in equal quantities for each particular sample, it was possible to compare the numbers of gastropod shells found in the individual samples. If the number of specimens obtained at washing was below the minimum necessary for processing (hundred specimens), so additional, larger quantities of material were subject to washing. In such cases, the material washed was doubled and the resulting number of specimens was halved.

The total number of taxons recovered from the 12.3 m sequence was 39. Considering that we are dealing predominantly with loess strata, this figure is considerable. Only in the case of the so-called wet-land loesses of the Great Hungarian Plain can a similar, though even richer, number of taxa be observed [M. ROTARIDES, 1931].

One of the causes responsible for the high number of taxa — though by far not the single cause — is that specimens of water-dwelling species (Tables 2—3) have also been recovered from the lower part of the sequence (10.5—12.3 m). These are species of great ecological tolerance living in standing water bodies or in waters of low kinetic energy. They may live and thrive even in minor ponds and pools including hardly any vegetation and they are able to survive even shorter or longer periods of drought when their habitat runs dry. Their sporadical occurrence can be explained by the presence of the so-called "semlyéks", *i.e.* intermittent minor

Quantitative occurrence of the molluscanfauna in the Madaras profile

TABLE 3

Serial number	Depth in m	Species																																		
		Vallonia enniensis (GREDL.)	*Vallonia tenuilabris* (A. BR.)		*Chondrula tridens* (MÜLL.)		*Clausilia dubia* DRAP.		*Clausiliidae indet.*		*Vitrea crystallina* (MÜLL.)		*Euconulus fulvus* (MÜLL.)		*Nesovitrea hammonis* (STRÖM)		*Vitrina pellucida* (MÜLL.)		*Semilimax semilimax* (FÉR.)		*Limacidae indet.*		*Discus ruderatus* (FÉR.)		*Punctum pygmaeum* (DRAP.)		*Bradybaena fruticum* (MÜLL.)		*Helicopsis striata* (DRAP.)		*Trichia hispida* (L.)		*Arianta arbustorum* (L.)		*Helicidae indet.*	
		pc.	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%
44	0—0,25		17	14,4	1	0,8	5	4,2			1	0,8	5	4,2											6	5,1					24	20,3				
43	0,25—0,50		5	5,2	11	11,5					2	2,1	1	1,0							4	4,2			1	1,0					17	17,7				
42	0,50—0,75		33	20,8	3	1,9	4	2,5					13	8,2	2	1,3					1	0,6			3	1,9					33	20,8				
41	0,75—1,0		138	18,6	3	0,4	15	2,0			17	2,3	78	10,5	10	1,3					2	0,3			35	4,7					279	37,7				
40	1,0—1,25		53	11,9			12	2,7			5	1,1	12	2,7	5	1,1							3	0,7	7	1,6					197	44,6				
39	1,25—1,50		71	13,3			26	4,9			3	0,6	65	12,2	6	1,1							1	0,2	38	7,1					228	42,7				
38	1,50—1,75		138	23,4			13	2,2					70	11,9	15	2,5									1	0,2					149	25,3				
37	1,75—2,0		73	17,4			24	5,7					50	11,9	7	1,7															120	28,6				
36	2,0—2,25		78	16,9			12	2,6					42	9,1	10	2,2															165	35,8				
35	2,25—2,50		34	11,8			50	17,3					86	29,8	4	1,4							1	0,3							90	31,1				
34	2,50—2,75		20	2,5			5	0,6					56	6,9	19	2,4															549	68,2				
33	2,75—3,0		109	12,9			15	1,8			1	0,1	64	7,6	27	3,2					4	0,5									220	26,0				
32	3,0—3,25		314	52,6	1	0,2	36	6,0					87	14,6	7	1,2					3	0,5			1	0,2					118	19,8				
31	3,25—3,50		203	29,0			20	2,9			5	0,7	118	16,9	15	2,1							2	0,3	5	0,7					149	21,3				
30	3,50—3,75		81	15,0			6	1,1			4	0,7	39	7,2	7	1,3							1	0,2	3	0,6					96	17,8				
29	3,75—4,0		116	19,9			24	4,1			9	1,5	94	16,2	1	0,2			1	0,2			8	1,4	26	4,5					255	43,8				
28	4,0—4,25		4	0,7			22	3,7			66	11,4	57	9,6	8	1,4	41	6,9	3	0,5	4	0,7	3	0,5	128	21,6					151	25,5	18	3,0		
27	4,25—4,50		12	1,6	1	0,1	2	0,3			73	9,7	34	4,5	24	3,2	31	4,1			3	0,4	2	0,3	323	42,9					131	17,4	5	0,7		
26	4,50—4,75		2	0,3			6	0,8			105	14,5	36	4,9	19	2,6	83	11,5	3	0,4	3	0,4	1	0,1	230	31,9					91	12,6	7	1,0		
25	4,75—5,0						9	0,8			129	11,4	43	3,8	18	1,6	123	10,9	6	0,5			1	0,1	449	39,8					91	8,1	15	1,3		
4	5,0—5,25		158	8,1			2	0,1			161	8,3	100	5,1	26	1,3	211	10,8	7	0,4			2	0,1	878	45,2					101	5,2	27	1,4		
3	5,25—5,50		44	2,6			1	0,1			201	11,9	103	6,1	19	1,1	148	8,8			1	0,1	11	0,6	955	56,7					89	5,3				
2	5,50—5,75						4	0,2			297	13,3	117	5,2	25	1,1	153	6,9							1434	64,3					112	5,1	2	0,1		
1	5,75—6,0		1	0,1			11	0,7			109	6,6	92	5,6	39	2,4	49	3,0			1	0,1			1262	76,6					24	1,5				
0	6,0—6,25		2	0,2	43	4,2	9	0,9			1	0,1	29	2,8	27	2,6	8	0,8			24	2,4			93	9,1					100	9,8	3	0,3		
9	6,25—6,50		1	0,2	35	8,0					1	0,2	3	0,7	14	3,2					34	7,7			3	0,7					91	20,7	7	1,6		
8	6,50—6,75		+	+	25	8,9					1	0,4			14	5,0					27	9,6			2	0,7					45	16,0	3	1,1		
7	6,75—7,0		5	0,9	50	8,8			1	0,2	3	0,5	3	0,5	27	4,8	1	0,2			20	3,5			16	2,8	2	0,4	13	2,3	36	6,9	2	0,4		
6	7,0—7,25				47	3,9					38	3,2	1	0,1	66	5,5					16	1,3			190	15,9	24	2,0			54	4,5	2	0,2		
5	7,25—7,50				43	5,4					11	1,4			40	5,0	1	0,1			24	3,0			27	3,4	7	0,9			73	9,1	7	0,9		
4	7,50—7,75				7	1,7					17	4,1	1	0,2	4	0,9					17	4,1					2	0,5			34	8,2	2	0,5		
3	7,75—8,0										43	7,7	6	1,1	15	2,7					28	5,8									343	61,4				
2	8,0—8,25		10	2,2	1	0,2					22	4,9	13	2,9							7	1,6									25	56,0				
1	8,25—8,50		37	4,6							13	1,6	67	8,4	11	1,4					4	0,5			19	2,4					466	58,3				
0	8,50—8,75										9	3,4	78	29,5	6	2,3									8	3,0					23	8,7	2	0,6		
9	8,75—9,0		2	0,1	5	0,2					65	3,0	69	3,2	128	5,9					89	4,1			368	17,1					352	16,4	8	0,4		
8	9,0—9,25												1	0,1							65	5,5			1	0,1			24	2,0	4	0,3				
7	9,25—9,50				17	5,0							2	0,6	2	0,6					6	1,8			20	5,9			1	0,3	1	0,3			1	0,3
6	9,50—9,75				30	7,9					5	1,3			5	1,3					7	1,9			14	3,7	5	1,3			1	0,3				
5	9,75—10,0				11	3,5															4	1,3	+	+					14	4,4						
4	10,0—10,50				4	6,3									1	1,6					3	4,7	+	+			+	+	+	+			+	+		
3	10,50—10,80				4	7,7	+	+							2	3,8					1	1,9	+	+					5	9,6						
2	10,80—10,90																																		+	+
1	10,90—11,30				+	+																							+	+					+	+
0	11,30—12,30	1							+	+																					+	+				

Quantitative occurrence of the molluscan fauna in the Madaras profile TABLE 2

Serial number	Depth in m	Sphaerium corneum (L.)		Pisidium cf. henslowanum (Shepp.)		Pisidium sp.	Valvata cristata Müll.	Valvata pulchella (Stud.)		Planorbis planorbis (L.)	Anisus spirorbis (L.)	Succinea elegans Risso	Succinea oblonga Drap.		Cochlicopa lubrica (Müll.)		Cochlicopa cf. lubricella (Porro)	Vertigo pygmaea (Drap.)		Vertigo alpestris Ald.		Granaria frumentum (Drap.)		Pupilla muscorum (L.)		Pupilla triplicata (Stud.)		Pupilla sterri (Voith)		Columella columella (Mart.)		Orcula dolium (Drap.)		Vallonia pulchella (Müll.)		Vallonia costata (Müll.)	
		pc.	%	pc.	%	pc.	pc.	pc.	%	pc.	pc.	pc.	pc.	%	pc.	%	pc.	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%
44	0—0,25												1	0,8										10	8,5	24	20,3	1	0,8	2	1,7	1	0,8			20	16,9
43	0,25—0,50												6	6,6										4	4,2	17	17,7			2	2,1					26	27,1
42	0,50—0,75												24	15,1										9	5,7	4	2,5			6	3,8					24	15,1
41	0,75—1,0												39	5,3										42	5,7	4	0,5	3	0,4	62	8,4	4	0,5			10	1,3
40	1,0 —1,25												62	14,0										24	5,4					49	11,0					13	2,9
39	1,25—1,50												33	6,2										10	1,9			2	0,4	51	9,6						
38	1,50—1,75												110	18,6										52	8,8			2	0,3	40	6,8						
37	1,75—2,0												91	21,7										34	8,1					20	4,8	1	0,2				
36	2,0 —2,25												61	13,2										57	12,4					18	3,9					18	3,9
35	2,25—2,50												17	5,9										1	0,3					–4	1,4					2	0,7
34	2,50—2,75												115	14,3										26	3,2					10	1,2	4	0,5			1	0,1
33	2,75—3,0												174	20,6										45	5,3			1	0,1	181	24,0	1	0,1			3	0,4
32	3,0 —3,25												19	3,2										4	0,7	1	0,2			6	1,0						
31	3,25—3,50												91	13,0										4	0,6					86	12,3					1	0,1
30	3,50—3,75												151	27,9	1	0,2								96	17,8					55	10,2						
29	3,75—4,0												25	4,3	2	0,3								12	2,1	+	+			5	0,9	1	0,2			3	0,5
28	4,0 —4,25												1	0,2	8	1,4								19	3,2	2	0,3					2	0,3			55	9,3
27	4,25—4,50												2	0,3	10	1,3								34	4,5	5	0,7			3	0,4	4	0,5			53	7,0
26	4,50—4,75														42	5,8								55	7,6	1	0,1					9	1,2			29	4,0
25	4,75—5,0														19	1,7								140	12,4							23	2,0	1	0,4	60	5,3
24	5,0 —5,25														17	0,9								118	6,1							46	2,4			89	4,6
23	5,25—5,50														16	0,9								15	0,9	5	0,3					50	3,0			26	1,5
22	5,50—5,75														8	0,4								56	2,5							1	0,1			20	0,9
21	5,75—6,0																							2	0,1	32	1,9			4	0,2					21	1,3
20	6,0 —6,25																							13	1,3	345	33,8									323	31,7
19	6,25—6,50																							51	11,6	8	1,8			1	0,2					191	43,4
18	6,50—6,75																							29	10,3	3	1,1									132	47,0
17	6,75—7,0																							49	8,6	30	5,3									310	54,6
16	7,0 —7,25														13	1,1								92	7,7	5	0,4									649	54,2
15	7,25—7,50														5	0,6								116	14,5	5	0,6									439	55,0
14	7,50—7,75														2	0,5								71	16,9	73	17,5									188	44,9
13	7,75—8,0																							74	13,2	2	0,4									47	8,4
12	8,0 —8,25																							86	19,2	2	0,4									55	12,3
11	8,25—8,50																							100	12,5	12	1,5			14	1,8					56	7,0
10	8,50—8,75																							15	5,7	115	43,6			2	0,8					7	2,7
9	8,75—9,0												60	2,9	1	0,1								495	23,0	58	2,7			3	0,1					443	20,6
8	9,0 —9,25																							223	19,0	785	66,5									77	6,5
7	9,25—9,50																					8	2,4	17	5,0	148	43,7									116	34,2
6	9,50—9,75																					36	9,6	3	0,8	84	22,3									186	49,5
5	9,75—10,0														1	0,3						3	0,9	3	0,9	269	85,4									10	3,2
4	10,0 —10,50							1	1,6									1	1,6	1	1,6	6	9,4	16	25,0									26	40,6	5	7,8
3	10,50—10,80	4	7,7	1	1,9					+					3	5,8		1	1,9			3	5,8	1	1,9	11	21,2							14	26,9	5	9,6
2	10,80—10,90																									+	+										
1	10,90—11,30					1																				2								2			
0	11,30—12,30					7	1	1		+	+	1					+	1				1		3		3										1	

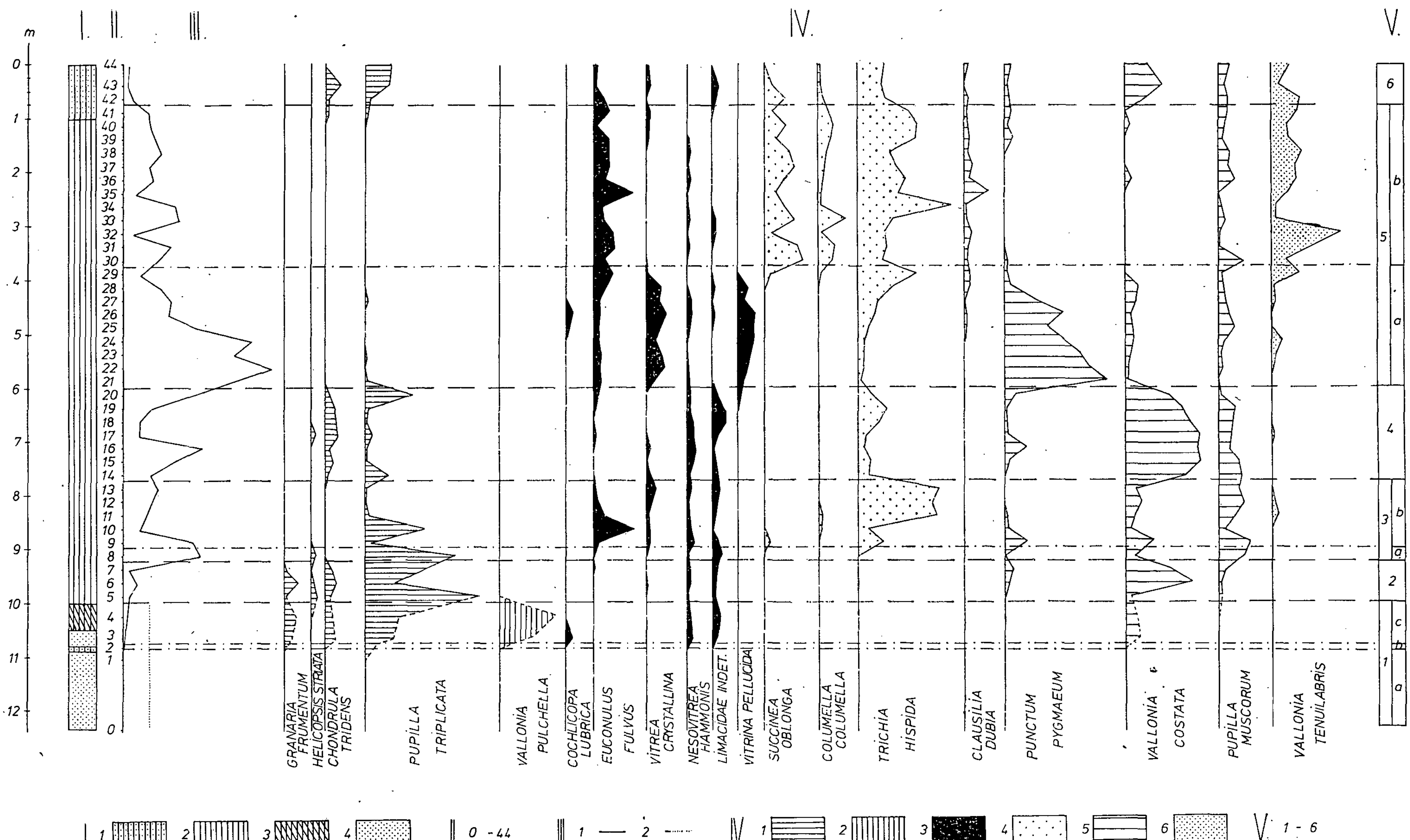

Fig. 4. Results of the paleontological study of the Madaras section
I. Same as in Fig. 3. II. Number of samples analyzed (Agrees with the number of samples figuring in Tables 2—3). III. Number of mollusc specimens recovered from the samples. 1. Diagram on the number of specimens, 2. The presence of water-dwelling species. IV. Curves of abundances of the comparatively more frequent species (1 mm=2%). V. Malacologically distinguished intervals. 1. to 6. Indication of single ecological types.

water pools, occurring even at present, as a result of the accumulation of water in more humid periods between sand dunes.

Between 0.0 and 10.5 m the fauna consists exclusively of terrestrial species (Tables 2—3). Most of the species found here are "loess snails" of high ecological valency, their habitats being land surfaces carrying a sparse vegetation. Much smaller is the number of those species living in bush and sparsely wooded areas, real forest-dwelling forms being totally absent in the fauna.

The quantitative study of the mollusc fauna has been based upon a total of about 30 thousand specimens selected from the washing residue. This quantitative analysis has showed rhythmical changes in the percentages of elements of different environmental and climatic demand. Given the subjectivity involved in the classification by various specialists of the gastropod species according to the character of the vegetation, the temperature and moisture demand of the animal, etc., we have relied first of all on the behaviour of the curves of abundances of the species in subdividing the sedimentary sequence on the basis of the mollusc fauna [E. KROLOPP, 1965, 1966, 1969]. Notably, it is obvious that curves of the same or similar behaviour imply that the species under consideration must have reacted in the same way upon environmental changes *(Fig. 4)*. On the basis of the detailed qualitative and quantitative examinations of the mollusc material of the samples the sedimentary sequence can be subdivided into the following intervals:

1. The 10.0—12.3 m interval is characterized by the appearance of water-dwelling and terrestrial faunas. The majority of the species living on land surface are highly thermophile *(Granaria frumentum* (DRAP.), *Pupilla triplicata* (Stud.), *Vallonia enniensis* (GREDL.), *Chondrule tridens* (MÜLL.), *Helicopsis striata* (DRAP.), cold-favouring elements being absent. Unfortunately, the sediment contains very few gastropod shells, so that even after the material had been rewashed only two samples could be quantitatively evaluated. Accordingly three subintervals can be distinguished:

1a) Between 10.9 and 12.3 m both water-dwelling and terrestrial forms occur in a very low number of specimens.
1b) The 10.8—10.9 m subinterval is characterized by a very poor fauna, so that only a few terrestrial forms were recovered as shell fragments.
1c) Although the 10.0—10.8 m subinterval shows a little richer fauna, the specimens per sample were in every case below a hundred in number, the calculated value of abundance thus being just informative (part indicated by broken line in *Fig. 4*). Beside thermophile forms, there is a remarkably high percentage of *Vallonia pulchella* (MÜLL.), a species very rare in loess-dwelling faunas and suggesting, again, a mild climate. The terrestrial species included some hydrophile elements as well.

2. In the 9.25—10.0 m interval the hydrophile elements are already absent. The thermophile species are still present, though with abundances smaller compared to the previous interval. The high frequency of *Pupilla triplicata* (STUD.), a species of similarly more or less high heat demand, and the great abundance of *Vallonia costata* (MÜLL.), a form, enduring even a drier climate and so of high ecological tolerance, are conspicuous features.

3. The 7.75—9.25 m interval comprises a characteristic "loess fauna". The total number of specimens recovered from the samples is considerably greater compared to the preceding intervals. Figuring only with a low number of specimens in the foregoing, *Pupilla muscorum* (L.) attains here a considerably high value of abundance. Beside it, *Pupilla triplicata* (STUD.), a species of even greater heat demand, is still present. *Vallonia costata* (MÜLL.) and *Trichia hispida* (L.) show diametrically opposite variations in abundances. Similar changes in the populations of other species typical of different, drier, environments or, on the contrary, characterized by a higher moisture demand, respectively, can be observed. The following subintervals can be distinguished:

3a) Between 9.0 and 9.25 m there is a transitional zone, where the number of specimens of *Pupilla triplicata* (STUD.), a more or less thermophile species, is still high.

3b) In the 7.75—9.0 m subinterval the abundance of thermophile elements, first of all, of *Trichia hispida* (L.), increases. Cold-indicating *Vallonia tenuilabris* (A. BR.) also appears. This is the depth range from which the artifacts and other archeological finds have been recovered.

4. In the 6.0—7.75 m interval the psychrophile elements decrease in abundance compared to the previous interval, while *Vallonia costata* (MÜLL.) enduring even a drier climate shows an increasing number of specimens. Some thermophile species also appear.

5. Between 75.0—6.0 m — especially in the lower one-third — a very high total number of specimens is characteristic. The fauna is a typical "loess fauna" in which, however, psychrophile elements occur in considerable number, too. The high frequency of *Vitrina pellucida* (MÜLL.) is noteworthy. Notably, this species is known from the loess sections thus far processed from just one or two localities, being represented by a few specimens only. *Semilimax semilimax* (FÉR.) is similarly rare in the loess. The following two subintervals have been distinguished:

5a) Between 3.75 and 6.0 m the very high total number of specimens is associated with the characteristic predominance of *Punctum pygmaeum* (DRAP.).

5b) The fauna of the 0.75—3.75 subinterval is characterized by the predominance of psychrophile and cold-enduring species (*Succinea oblonga* DRAP., *Columella columella* (MART.), *Euconulus fluvus* (MÜLL.), *Trichia hispida* (L.). Cold-indicating *Vallonia tenuilabris* (A. BR.) also occurs in considerable number of specimens.

6. Between 0.0 and 0.75 m, the abundance of psychrophile species decreases in relation to the previous interval. Thermophile elements highly tolerant of drought appear, showing particularly high abundances in the 0.25—0.50 m depth range. Otherwise, the total number of specimens decreases.

In the light of the quantitative study of the mollusc fauna the ecological conditions of the individual intervals can be characterized as follows:

1. At the time of the deposition of the lower part of the sedimentary sequence concerned the climate seems to have corresponded to the present-day one or possibly more inclined to the extremes. Intermittent pools (semlyék") seem to have formed in the more humid periods in which even a water-dwelling fauna appeared for a short span of time. There did not exist, however, any considerable forestrial vegetation. In the 10.8—10.9 m interval, in compliance with loess formation, the fauna suggests a drier climate.

2. The fauna of the 9.25—10.0 m interval indicates a climate turning drier.

The decrease in the number of species is indicative of the decline of vegetation as well.

3. The fauna of the 7.75—9.25 m interval is suggestive of a cool and humid climate and a grassy or, at most locally, bush-strewn vegetation.

4. In the 6.0—7.75 m interval the sedimentation seems to have taken place under a climate that was a little drier and warmer compared to the previous case.

5. The fauna of the 0.75—6.0 m interval is indicative of a cool, humid and then explicitely cold climate. The land surface was grown with grass locally dotted with shrubs.

6. It was only at the time of the 0.0—0.75 m interval that the climate was warmer. However, the vegetation is even here deprived of any features that might be indicative of forests, being of grassland or bush character.

The reconstruction of the one-time climate is valid primarily to the growing season, *i.e.* that lasting from spring to autumn. Notably, the life of gastropods is most heavily influenced by the temperature and precipitation conditions of these seasons. They survive the period from the autumn to the spring mainly in an inactive state, thus being less affected by the corresponding climatic influences.

The analysis of the behaviour of the curves of gastropod abundances from Madaras has enabled us not only to reconstruct how the environment looked like at sedimentation and to subdivide the sequence malacologically, but it has called attention to a couple of peculiarities which may be relied on subsequently when studying other latest Pleistocene geological sections. So it is worthy of mention that in intervals, where the fundamental ecological factors appear to be uniform, the curves of abundances obtained for *Punctum pygmaeum* (DRAP.) and *Trichia hispida* (L.) may *quasi* replace each other. It is obvious that the ecological requirements of the two species are not completely identical, this being that feature enabling us to distinguish further subdivisions within single major intervals. In addition, it is also peculiar that the curves of psychrophile species of smaller population run parallel.

The washing residue of samples has yielded, in addition to molluscs, some vertebrate fossil remnants as well. L. KORDOS has given the following description of bone remains of this kind:

In the 10.9—11.3 m interval there was a fragment of the lower incisor of 1 specimen of a small-sized vole (? *Microtus*). The 8.75—9.0 m interval yielded one upper incisor fragment and and another tooth fragment belonging to *Sorex araneus* L. In the same interval there were, in addition, one M^1 and one M^3 of *Myodes glareolus* (SCHR.) and fragments of the lower incisors of 2 small-sized voles (? *Microtus*) *Arvicilidae indet.* The 8.50—8.75 m interval produced one bone splinter of *Micromammalia indet.*, 7.25—7.50 did so 2 fragments of egg shells of *Aves indet.*, 5.75—6.0 m yielded *Myodes glareolus* (SCHR.), one M_2 (?) fr. and, finally, 5.50—5.75 was found to contain 12 specimens of 3—4 mm size of bone splinters belonging to a *Mammalia indet.*

None of the vertebrate finds indicates an extremely cold climate, but it suggests rather a humid environment of lush vegetation. Unfortunately enough, the finds are of no exact chronological value.

Relying on the mollusc fauna thus far available, the vertebrate remains and other earlier data, we can attempt at giving the following chronology of the Madaras sequence:

The wind-blown sands at the base of the sequence could have settled in a mild climatic phase. However, the time of deposition could not correspond to the Riss—Würm interglacial, but might be identified only with one of the "interstadials" distinguished within the Würm glacial [E. KROLOPP, 1973]. If it is identified with the Würm$_1$—Würm$_2$ interstadial, then on evidence of malacological studies of loess exposures in the neighbourhood of the Mecsek Mountains it seems to be presumable that the loesses of the subsequent cool and then totally cold climates represent a younger part of the Würm, *i.e.* the Würm$_2$ and Würm$_3$ stadials. As can be determined, however, erosion has removed all the sediment that used to cover the land surface originally. Thus it seems to be not at all improbable that a part of the loess layer that would correspond to the Würm$_3$ stadial is already missing from the section. The warm spell observed in the final part of the Madaras section would, more sandy in facies as it is, thus represent a Würm$_2$—Würm$_3$ warming up of the climate, or mean a minor mild phase within Würm$_3$ — an assumption that seems to be very plausible when the general geochronological evolution of the Bácska Loess Area, to be presented later, is taken into consideration.

Putting the interval boundaries obtained sedimentologically and paleontologically for the Madaras section side by side, it will be seen that the boundaries will coincide in most cases (*Fig. 3,* items III and IV). Where there is a difference, as for instance in the 1st and 6th intervals, this is due to the fact that changes in the conditions of sedimentation are followed with some delay by the corresponding changes of the fauna. In other words, a new biotope will not be formed until and unless the sedimentary environment has changed, succeding, in some way, to it: a process associated, in certain cases, with some time shifts. Excepting this, the variations of the sedimentological characteristics and the character of changes in the mollusc fauna are in a good harmony with one another.

For example, as implied by the sedimentological characteristics, the 1st interval showed a wide range of changes in the kinetic energy of sedimentation. A diversified hydrophile and terrestrial faunal assemblage appeared in the same interval. The sedimentological features in the 2nd interval are more steady than in the first one, while the fauna is characterized by features suggestive of a drought-inclined climate and by the reduction of the number of species. The 3rd interval witnessed a steady sedimentation, though disturbed by minor climatic changes. The fauna suggests a cool and humid environment. In the 4th interval the sediment was deposited by kinetic energies a little greater but a little even more steady than the former. The trend of becoming more steady is indicated in the fauna by the predominance of species characteristic of a climate that was drier and warmer than that of the previous interval. In the fifth phase the depositional energy was most steady and best balanced within the entire section under study. This fact is indicated in the fauna by the appearance of species suggestive, especially in the upper part, of a cooler climate. Finally, in the 6th interval the kinetic energy responsible for sedimentation increased to such an extent that it became unsteady with rapid, shock-like changes in its dynamics. In the fauna, this change is indicated by the appearance of thermophile species.

LATEST PLEISTOCENE GEOHISTORICAL EVOLUTION OF THE BÁCSKA LOESS AREA

The latest Pleistocene history of the Bácska Loess Area can be illustrated and explained by relying on the earlier geological surveys undertaken by I. MIHÁLTZ and L. MOLDVAY, on the relevant studies performed by B. MOLNÁR and on the Madaras section processed as well as on the observations made during field traverses by the present writers [in: I. MIHÁLTZ, 1953, B. MOLNÁR, 1961, 1970, 1975).

As shown in the introductory part, the eolian sequence of the Bácska Loess Area shows a N—S and E—W directed reduction in thickness. The northern part of the study area was explored by the Szentes—Baja section studied by I. MIHÁLTZ and L. MOLDVAY down to 30 m depth, and examined in detail over the Baja—Felső-szentiván—Jánoshalma stretch *(Fig. 1)*. In this northern area the following geological formations have been encountered down to a depth of 30 m:

At 30 m depth, loess has been uncovered throughout the section under study. It is overlain by wind-blown sands in 5 to 10 m thickness. The wind-blown sands are followed, in turn, by a three-membered loess horizon divided by wind-blown sand layers of 1 to 3 m thickness. Two of the three loess subhorizons, *i.e.* the upper and the lower ones, are present throughout the study area, whilst the middle one is absent in a number of places. I. MIHÁLTZ assigned the upper three loess subhorizons and the wind-blown sand layers between them, to the Würm. In the west the topmost loess surface is overlain by Holocene wind-blown sands. The thick windblown sand layer underlying the three-membered loess horizon can be assigned to the Riss—Würm interglacial, while the loess occurring at 30 m depth might belong to the Riss glaciation already.

The same geology can be expected to occur in the more southern Hungarian share of the Bácska Loess Area, the only difference being, at the most, that the role of the interbedded wind-blown sand layers may be reduced, to become totally absent in several places over the Yugoslavian part of the area.

Thus the Madaras section has exposed, even on the basis of the above considerations, a part of the loesses of Würm age. The wind-blown sand occurring at the base of the section, was deposited, as shown in the light of the fauna, in a span of time characterized by a rather mild climate. This interval has been identified with the Würm$_1$—Würm$_2$ interstadial. With a climate turning colder, loess sedimentation started. This was the time when the thin layer of the Pseudomycelium-bearing, sandy loess of the 10.8—10.9 m interval was formed. However, the transition into the colder climatic phase seems to have been characterized by some oscillations,

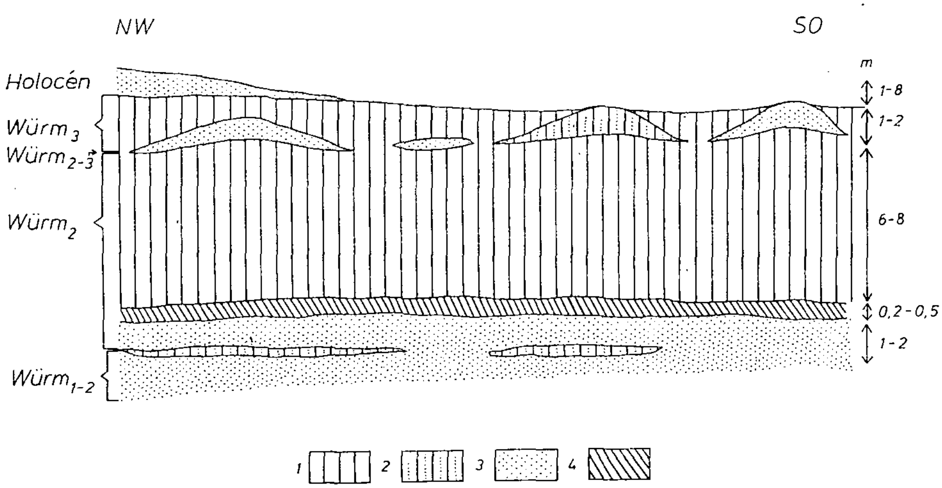

Fig. 5. Idealized sketch of the Latest Quaternary history of the Bácska Loess Area. 1. Typical loess, 2. Sandy loess, 3. Wind-blown sand, 4. Soil horizon.

as the thin loess layer is first overlain by wind-blown sands, to be then followed again by loess in which, however, a kind of chernozem soil was formed. It was only after this that a virtually longer cold loess deposition period followed, resulting in the formation of 8—9 thick loess layers. The initial grading of the climate into a colder one and its periodical oscillations are readily shown and reflected by changes in the fauna as well.

Fig. 5 shows the Latest Quaternary (since the Würm$_1$—Würm$_2$ interstadial up to the present) geohistory as demonstrable on an idealized sketch in NW—SE direction. At the base there is a thin, hardly 1—2 m, layer of wind-blown sands deposited in the Würm$_1$—Würm$_2$ interstadial. In some places, as could be seen at Madaras as well, a thin Pseudomycelium-bearing loess appears in the wind-blown sand layer. This is followed by a chernozem-like soil which is rather common throughout the study area, being present, e.a., even in the section at Katymár.

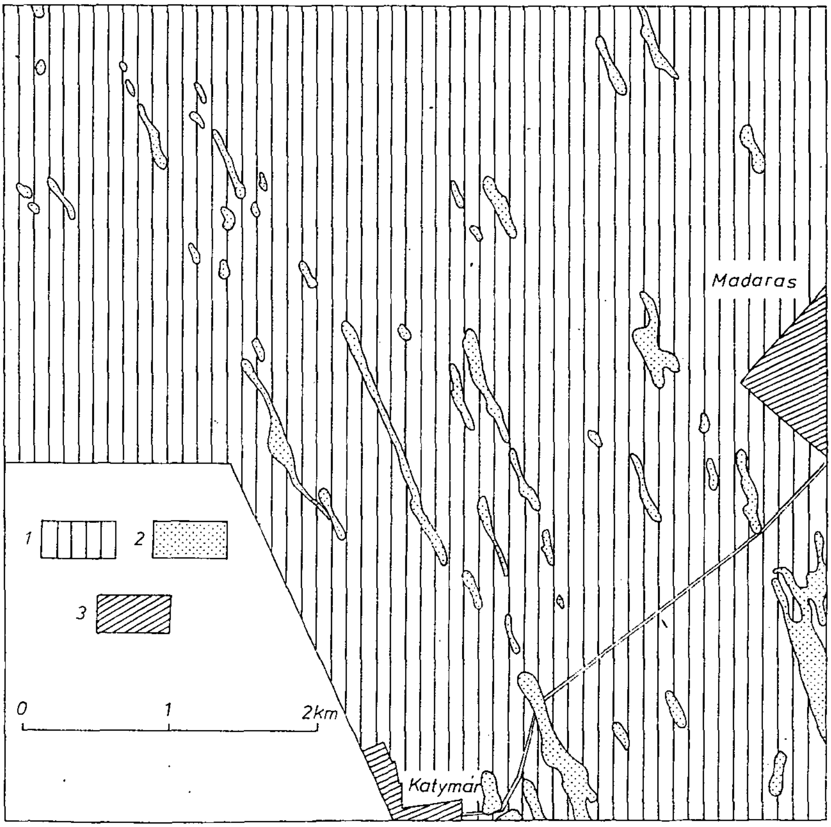

Fig. 6. Large-scale geological map of the Katymár-Madaras area.
1. Typical loess, 2. Wind-blown sand, 3. Settlement

The soil horizon has been overlain, in 6 to 10 m thickness, by typical loesses of the Würm$_2$ stadial. In the Würm$_2$—Würm$_3$ interstadial the one-time loess surface was blanketed by wind-blown sand brought by the predominant winds from the northwest. This wind-blown sand appears in the majority of the cases as a lens or as minor sand dunes. Its material is not always sand, but all types of transition from sand to loess may be represented. Consequently, it is represented by sandy loess or loessy sand. Where the loess overlying it and of later origin was removed by erosion, the wind-blown sand is exposed in the form of northwest-southeast trending bars of sand dunes, as can be seen on the large-scale geological map of the Katymár—Madaras area *(Fig. 6)*. In the Katymár exposure the wind-blown sands of the Würm_2—Würm_3 interstadial are present in the form of a thin sand layer *(Fig. 7)*.

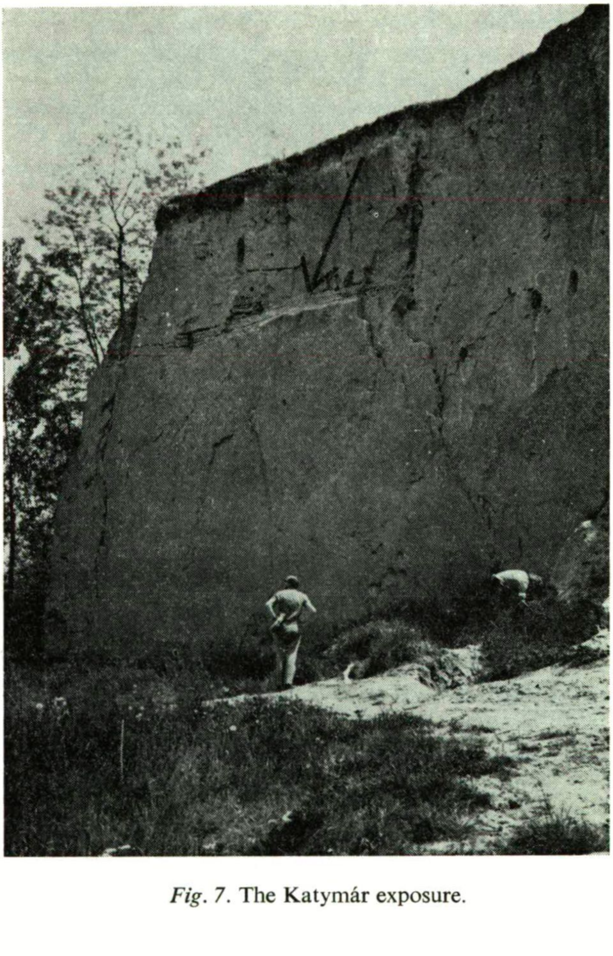

Fig. 7. The Katymár exposure.

Thus the loess of the last stadial (Würm_3) must have developed already on a surface covered by bars of sand dunes. In Holocene time winds coming from the northwest deposited again eolian sands in the northwest part of the Bácska Loess Area. However, the major part of the area is characterized, in the Holocene, by erosion processes such as soil erosion, rather than by accumulation.

SUMMARY

The Hungarian share of the Bácska Loess Area is exposed in numerous geological sections *(Figs. 1, 2)*. Out of the sections most typical of the geology of the study area, that of Madaras was studied in detail both sedimentologically and paleontologically and the results were compared with ones obtained for other sections. Using this and also earlier informations, the authors have sketched up the Latest Quaternary geohistory of the study area *(Fig. 3, 4, 5)*.

On the basis of the sedimentological features and according to the mechanism of sedimentation and changes in its kinetic energy, several minor intervals and subintervals could be distinguished even within vertical stretches appearing to be totally homogeneous to the unaided eye. The intervals and subintervals thus distinguished are in good agreement with the relevant paleontological results (*Fig. 3,* items III and IV). Wherever any, differences between the two types of interval boundaries are due to some delay with which a new biotope and the associated changes in the fauna tend to follow the establishment of a new regime in the sedimentary environment.

In the mollusc fauna of the Bácska Loess Area the thermophile species are present in greater number as compared to the case of the typical Transdanubian loesses [E. KROLOPP, 1965. 1966]. On the basis of some other peculiar features of the fauna (e.g. the presence of *Vitrina pellucida* (MÜLL.) and the high abundance of *Punctum pygmaeum* (DRAPP.)) the Bácska loess fauna differs from the loess faunas of other areas. These observations encourage even the possibility of regional correlations of subdivisions within the loess sequence.

REFERENCES

CAILLEUX, A. [1952]: Morphoskopische Analyse der Geschiebe und Sandkörner und ihre Bedeutung für die Paläoklimatologie. — Geol. Rundschau *40,* Stuttgart, p. 11—19.

FOLK, R.L.—WARD, W.C. [1957]: Brazos River bar: A study in the significance of grain size parameters. — Journ. Sedimentary Petr. *27,* p. 3—27.

INMAN, D.L. [1952]: Measures for describing the size distribution of sediments. — Journ. Sedimentary Petr., *22,* 3, p. 125—245.

KRETZOI M.—KROLOPP E. [1972]: Az Alföld harmadkor végi és negyedkori rétegtana az őslénytani adatok alapján. — Földr. Ért., *21,* 2—3, p. 133—158.

KROLOPP, E. [1965]: A Dorog—Esztergomi-Medence pleisztocén képződményeinek biosztratigráfiai vizsgálata (Biostratigraphische Untersuchung der Pleistozänbildungen des Dorog—Esztergomer Beckens). — Magy. Áll. Földtani Int. Évi Jel. 1963. évről, p. 133—145.

KROLOPP, E. [1966]: A Mecsek hegység környéki löszképződmények biosztratigráfiai vizsgálata (Biostratigraphische Untersuchung der Lössbildungen in der Umgebung des Mecsek-gebirges). — Magy. Áll. Földt. Int. Évi Jel. 1964. évről, p. 173—189.

KROLOPP, E. [1969]: Die jungpleistozäne Molluskenfauna von Tata (Ungarische VR.). — Ber. deutsch. Ges. geol. Wiss., Geol. Paläont., *14,* p. 491—505.

KROLOPP, E. [1970]: Őslénytani adatok a Nagyaldöld pleisztocén és felsőpliocén rétegek sztratigráfiájához. (Paläontologische Beiträge zur Stratigraphie der Pleistozänen—Oberpliozänen Schichtenfolge der Grossen Ungarischen Tiefebene.) — Őslénytani Viták *14,* p. 5—43.

KROLOPP, E. [1973]: Quaternary malacology in Hungary (Negyedkori malakológia Magyarországon). — Földr. Közl., *21,* 2, p. 161—171.

MIHÁLTZ I. [1953]: A Duna—Tisza köze déli részének földtani felvétele. — Magy. Áll. Földt. Int. Évi Jel. az 1950. évről, p. 113—143.

MOLNÁR, B. [1961]:. Die Verbreitung der äolischen Bildungen an der Oberfläche und untertags im Zwischenstromland von Donau und Theiss. — Földt. Közl., *91,* 3, p. 300—315.

MOLNÁR, B. [1964]: On the relationship between the lithology of the abrasion area and the transported sediments. — Acta Miner. Petr. Szegediensis *16,* 2, p. 69—88.

MOLNÁR, B. [1966]: Veränderungen der Abtragungsgebiete auf der Grossen Ungarischen Tiefebene während des Pliozäns und Pleistozäns. — Földt. Közl., *96,* 4, p. 403—413.

Molnár, B. [1970]: Pliocene and Pleistocene Lithofacies of the Great Hungarian Plain. — Acta Geol. Ac. Sc. Hung., *14*, p. 445—457.
Molnár, B. [1973]: Latest Tertiary and Quaternary Accumulation cycles of the Great Hungarian Plain. — Földt. Közl., *103*, 3—4, p. 294—310.
Molnár, B. [1975]: A Duna—Tisza köze felső-pliocén és pleisztocén földtani fejlődéstörténete. — Földtani Közl., *107*, 1, p. 1—16.
Rotarides, M. [1931]: Die Schneckenfauna des ungarischen Lösses und die ungarische rezente Schneckenfauna mit besonderer Berücksichtigung der Lösse von Szeged. — A Szegedi Alföldkutató Bizottság Könyvtára V. A. 8. Szeged. p. 1—180.
Stieber, J. [1967]: A madarasi löszprofil faszeneinek vizsgálata. — Archeológiai Értesítő *94*, 2, p. 192—193.
T. Dobosi, V. [1967/a]: Új felsőpaleolit telep az Alföldön. — Archeológiai Értesitő *94*, 2, p. 184—192.
T. Dobosi, V. [1967/b]: Die Rettungsgrabung in der Jungpaläolitischen Siedlung von Madaras. — Móra F. Múzeum Évk., 1966—1967, Szeged, p. 5—11.

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PALAEOZOIC AND PRECAMBRIAN FORMATIONS OF THE ALGYŐ, FERENCSZÁLLÁS AND KISKUNDOROZSMA AREAS

T. KOVÁCS G.

ABSTRACT

In the central part of the Southern Great Plain (Szeged environment, between 1965 and 1977) about 150 hydrocarbon exploratory bores reached the metamorphic basement.

The stratigraphic identification of the crystalline formations with those of the neighbouring countries shows that the metamorphites of this area are also of Precambrian origin. The Precambrian formations of the Codru Mountains can be traced probably through the Pusztaföldvár area to the Algyő—Ferencszállás range (Biharia and Baia de Arieş series). The classification of the metamorphites of Kiskundorozsma is not clear yet. The formation and stratigraphic position of the rock seems to be similar to the Someş and Baia de Arieş series of the Bihor-autochton as well as to the Lower Crystalline Sequence of the Serbo—Macedonian Massif. The Paleozoic is represented by the incompletely verified Carboniferous metamorphite breccia (Szeged, Algyő) and by the pegmatite and granite porphyre dykes penetrating the metamorphites (Ferencszállás).

INTRODUCTION

In the Southern Great Plain the metamorphic and granitoid formations as basement were explored by the hydrocarbon bores thus these could be studied only in the past two decades. The identification of the main rock types seems to be solved. The rocks are characterized by the metamorphic belts of the BARROW-type facies series. To elucidate their genesis and position the study of SZEPESHÁZY K. [1973] entitled "Relations of the metamorphic formations of the Carpathians and of the Great Plain" was used which among others, reproduces the description of the Apuseni Mountains from the structural-geological point of view. The macroscopic identification was promoted by the correlation of SZEDERKÉNYI T., *i.e.* the correlation of the metamorphic and granitogenic rock samples of the Hegyes—Drócsa Mountains with the crystalline formations of the Szeged environment. When making the stratigraphic classification we tried to distinguish the pre-Riphean garnetiferous, staurolite-bearing paragneisses and biotitic mica-schists and the Riphean sericitic, chloritic, albitic, epidote-bearing chlorite-schists, amphibolites, porphyroids and crystalline limestones which are believed to be produced mostly by the products of igneous activity.

During the evaluation the petrographic determinations and publications of the geologists [JUHÁSZ, Á., CSONGRÁDI, B., SZALAY, Á. and SZEPESHÁZY, K.] of the Department of Geological Data Processing of the National Oil and Gas Industrial

Trust as well as of its legal successor, *i.e.* of the National Oil and Gas Industrial Laboratory, were used.

In this study, in addition to the demonstration of the deep-geological conditions, the geological conclusions which can be drawn from the results and investigations carried out till now, are tried to be summarized, further an attempt is made to insert the metamorphic formations of the Szeged environment in the marginal Carpathian geological unit.

It is to be noted, however, that in spite of the large amount of data this latter can be done only with numerous restrictions. The uncleared correlation problems occurring within the crystalline rocks of the Apuseni Mountains and of the Southern Carpathians, the unsolved relation of the Serbo—Macedonian and Pannonian Massifs as well as the petrographic and tectonic elaboration of the crystalline basement of the Great Plain being insufficient to make correlations, all these considerably restrict the correlation works. Nevertheless, it is believed that on the basis of the up-to-date interpretation of the available mass of data the first rather hypothetic statements can be concluded which may serve as a basis for a later more detailed correlation work.

PROTEROZOIC

83 boreholes reached the crystalline basement (between 2450 m and 3150 m) in more than 500 ones drilled at Algyő. Numerous varieties of the diaphtorized rocks were known from these boreholes. The new investigations do not verify the triple arrangement of the series determined by Völgyi L. *et. al.* [1970] and others on the basis of rock types. Making denser the borehole network the more detailed analysis of the horizontal changes of the rocks proved to be possible. As a result of newer investigations a capricious occurrence and distribution of rock-types is demonstrated.

In the western and eastern side of the block range fault lines of NW—SE direction are found. The boreholes lying west of the fault line (e.g. No. 14 and 106) did not reach the surface of the submerged crystalline basement. These boreholes were stopped in the eroded coarse-clastic sequence of metamorphite material of the block range. The cover is formed by Lower Pannonian conglomerate, lime-marl and marl. In the western part Sarmatian and Lower Tortonian clastic sequences are also found [T. Kovács, G., 1975]. Also in the western part, e.g. in the borehole No. 29 Middle Triassic dolomite was found.

The detailed introduction of the crystalline rocks of Algyő is reasoned by the unique formation of metamorphites in the Southern Great Plain. Areal distribution of the characteristic rock types is shown in *Fig. 1.*

In the southern part, in the neighbourhood of parametamorphites light-grey, slightly schistose *porphyroids* of porphyroblastic texture were found in the boreholes Deszk-1, Deszk-1/a, Algyő-30, 54 and 56. These were generated by acid igneous products on the effect of regional metamorphism. Sill-like rock bodies can be assumed since below the porphyroid feldspar-bearing mica-schist in the borehole No. 54 and mica-quartzite in the borehole Deszk-1 were found. According to the studies of Szepesházy K. [1974] the fine quartz-feldspar grains and muscovite lamellae surround the orthoclase and plagioclase plates of more than 1 to 2 mm as well as the microcline crystals and albite grains. The recrystallization of the original feldspar content in form of microcline and albite was produced by the metasomatism accompanying the polymetamorphism. Accordingly, this is not re-melting or granitization as assumed by Völgyi L. *et al.* [1970] and Szalay Á. [1977] but rather

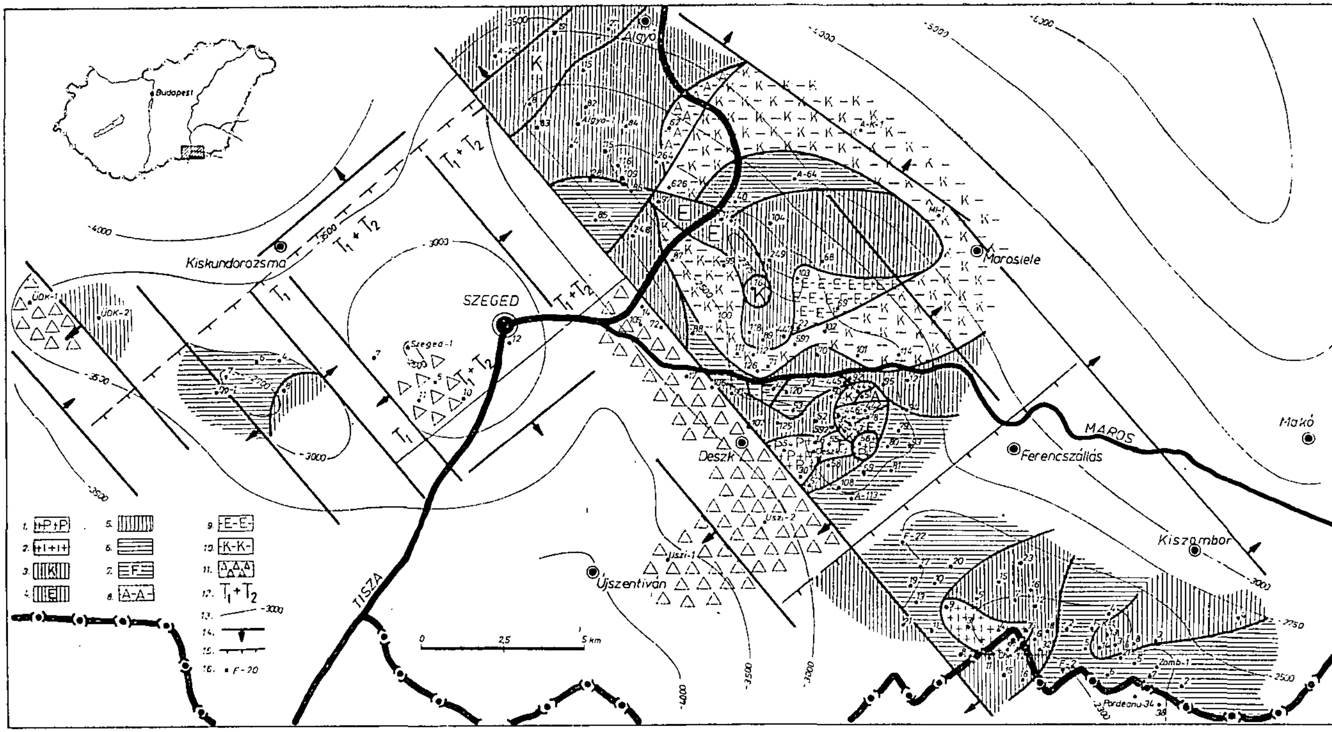

Fig. 1. Deep-geological and structural map of the central part of the Southern Great Plain. Constructed by T. KOVÁCS, G. [1978]. — Legend: *1* — porphyroid, *2* — granite porphyre and pegmatite veins, *3* — chlorite gneiss, *4* — actinolite-epidote gneiss, *5* — muscovite-biotite gneiss, *6* — muscovite-biotite mica-schist, *7* — phyllite, *8* — amphibole-schist, *9* — epidote schist, *10* — chlorite-schist, *11* — metamorphite breccia, *12* — Lower and Middle Triassic formations, *13* — contour lines of the surface of the basement, *14* — fault line, *15* — overthrust line, *16* — sign and number of boreholes.

a retrograde process subsequent to metamorphism. The porphyroid is a subvolcanic intrusion. It represents the youngest member of the metamorphic sequence but its formation precedes by all means the metamorphism.

In the northernmost part of the Algyő Block light greyish-green slightly schistose *chlorite-gneiss* suffered retrograde metamorphism was found (boreholes No. 8., 19., 26. and 27). These rocks might be formed from terrigenous sediments of greywacke type. The old potash feldspar is represented by microcline and orthoclase. The plagioclase content is very high. Most of the feldspars is sericitized. Among phyllosilicates chlorite is predominant, but biotite can also be found. The young albite also appears. The chlorite-gneiss of the borehole No. 16 can be assigned to this group, which, on the basis of the investigations of K. Szepesházy [1974] is fine-grained and in the groundmass consisting of quartz, feldspar and muscovite crystals quartz knots and acid plagioclase crystals are found. Biotite is completely chloritized.

In the central part of the block range, *i.e.* in the boreholes No. 11., 97. and 117 green-coloured *actinolite-epidote-gneisses* are found, derived from terrigenous sediments and basic pyroclastite on retrograde effects. According to Á. Szalay [1969] the main constituents of the rock are: quartz, plagioclase, potash feldspar, epidote, actinolite, green-amphibole, calcite and muscovite. Chloritization and albitization can also be observed.

The *gneisses* of sedimentary origin (psammitic, partly tuffic) are of general extension. The mineral composition of the greyish-green fine- or medium-grained rocks of different schistosity is usual, *i.e.* these consist of quartz, plagioclase, muscovite and biotite. The staurolite, zircon and epidote are less frequent. The subsequent transformation has, however, changed this picture. Chloritization, sericitization and albitization is not only due to the diaphtoresis but also to the metasomatic effect. According to the investigations of Szalay, Á. [1977] the rock hardly contains primary potash feldspar and the primary oligoclase is often sericitized. Two kinds of gneisses were developed.

The greenish-grey sometimes garnetiferous *muscovite-biotite-gneiss* is found in the northern part (in the boreholes No. 4., 15., 82., 83., 84., 109., 115., 116. and 264.). Its feldspar crystals are partly zoisitized or albitized. Epidote strips also occur. The remnants of the older potash feldspar are represented by the small amount of microcline and orthoclase. The borehole No. 109. represents the transition between the biotite-gneiss and biotite-mica-schist (borehole No. 86.). The transitions occur also vertically, e.g. in the borehole No. 15. the gneiss transits into muscovite-biotite mica-schist. In the southern part the two-mica-gneisses occur in four localities. The gneisses of the boreholes No. 94., 95 and 121. are characterized by the appearance of garnet. Staurolite, zircon and apatite were found in the boreholes No. 57. and 58. In the boreholes No. 68., 90. and 125. the rock is schistose and stratified. The sericitic orthoclase, muscovite and chloritized biotite alternate with quartz strips. Magnetite and epidote occur as accessory minerals.

In the central and southern part of the area *biotite-gneisses* of spot-like occurrence were found. The feldspars of the greenish-grey gneisses are sericitized (in the boreholes No. 50., 52., 55. and 248.). The biotite is partly chloritized. The potash feldspar is represented mostly by orthoclase. Garnet, zoisite and magnetite occur also in this type of rocks. The boreholes No. 70. and 92. are characterized by low quartz and high plagioclase contents, while in those No. 248. and 447. the high biotite content is characteristic. The formation of albite can be observed in the borehole No. 104.

The one- and two-mica-schists of sedimentary origin and of low feldspar content are found in the central and southern part of the area. Similarly to the gneisses these can be also characterized by multi-generation mineral assemblages. The main mineral constituents are the quartz, muscovite, biotite and plagioclase. Garnet, epidote, staurolite, chlorite and calcite are the accessory minerals. The transition among the mica-schists, basic metamorphites and gneisses is gradual.

The boreholes No. 28., 31., 442., 443. and 445 explored greenish-grey *muscovite-biotite-mica-schist.* Chloritization and sericitization are of different measure. In the southernmost part of the Algyő area (boreholes No. 59., 79., 80., 81., 93., 108. and 113.) only *biotite-mica-schists* are found. In the borehole No. 59. staurolite can also be determined. In the southern and eastern part of the area (boreholes No. 40., 64. and 120) chloritic, garnetiferous *muscovite-mica-schist* was found. The sericitic, chloritic, garnetiferous *biotite-mica-schist* is known from the boreholes 53., 85. and 91. In the borehole No. 86 the biotite/chlorite ratio is less than 50 per cent, thus it is qualified as *chlorite-biotite-schist.* Chloritic, biotitic, feldspar-bearing *mica-quartzite* was found in the boreholes No. 88. and Deszk-1.

In the southern areas (boreholes No. 32., 55. and 78.) greyish-green schistose *phyllites* were found. These consist only of sericite and quartz. In the borehole No. 78. small quantity of chlorite and amphibole also occurs; these accompany the mica-schists. The same assemblage is found under biotite-gneiss in the borehole No. 55.

In the central part of the Algyő block the *green chlorite-schist, epidote-schist* and *amphibole-schist* are found in wide areal extension. These might form from basic initial igneous products, lavas and tuffs. This is expressed not only by the random extension but the relations of their settlingtoo. These are situated in mica-schists and gneisses, e.g. in the borehole No. 62 the amphibole-schist is overlain by mica-schist, in the borehole No. 99. the chlorite-schist is underlain by gneiss while in the borehole No. 626 the sequence is gneiss, mica-schist, chlorite-schist.

The *chlorite-schists* have largest extension. These can be found in the boreholes No. 71., 87., 99., 100., 101., 102., 111., 112., 114., 126., 443., 444. and 626. The rocks found in the boreholes Maroslele-L and Algyő-East-1 are believed to be the same rocks. The main constituents of chlorite-schists are quartz. chlorite and albite. Chlorite is predominant. The rock contains locally small quantities of feldspar, muscovite, epidote and calcite and is of fine-grained schistose structure.

Epidote-schists were discovered by the boreholes No. 22., 69. and 103. According to the investigations of SZEPESHÁZY, K. [1974] these rocks are fine-grained and moderately schistose. Most of the rock consists of quartz grains, epidote and chlorite crystals. The feldspars also occur and consist predominantly of plagioclase. Orthoclase, magnetite and apatite can also be determined.

Amphibole-schists occur in the boreholes No. 51. and 62. This rock is dark-green, fine-crystallized, compact and slightly schistose. It consists mostly of green amphibole and subordinately of plagioclase. Quartz, garnet, tremolite and epidote are the accessory minerals.

Regarding the parent rocks of Algyő metamorphites they formed a single depositional cycle from the pelites up to the psammites inclusive. There are irregular settling-structures in this sedimentary complex due to the lava flows and tuffs originated from initial magmatism produced some transitional rock-types, too. This sedimentary complex were penetrated by sill-like porphyroid bodies being youngest rocks prior to the metamorphism The formation of rocks took probably place in the Late Precambrian. Due to the subsequent diaphtoresis and metasomatic effect the metamorphites have undergone large-scale transformation. In harmony with the BARROW-type facies sequences the staurolite-almandine subfacies of the almandine-amphibolite facies as well as all the three subfacies of the greenschist facies can be determined. The metamorphites consist mostly of the rocks being characteristic of the greenschist facies. The middle subfacies is predominant (quartz-albite-epidote-biotite) and most of the gneisses, mica-schists and epidote-schists can be assigned also to this group.

The formation of the metamorphites seems to be similar to that of the Baikalian Biharia Sequence of the Codru Mountains. The substance of metamorphites was provided here also by basic and acid initial igneous products as well as by terrgineous sediments.

The southern continuation of the Algyő area is the Ferencszállás (F), Ferencszállás-East (FK) and Kiszombor (Zomb) uplifted block. 60 boreholes were drilled in this area (between 2250 and 2600 m), 55 of them reached the basement, while in 20 of them no core samples were drilled. The borehole Zomb-4. reached the crystalline basement in a depth of 2804 m. The cover consists of Lower Pannonian conglomerate and lime-marl. The metamorphic rocks showing strip-like arrangement consist of mica-schists and gneisses *(Fig. 1)*. The horizontal change is accompanied by a vertical one, e.g. in the borehole FK-1. in the mica-schist there is a gneiss intercalation while in the borehole Zomb-4. the gneiss transits into mica-schist. Chloritization can be nearly always observed. The folded, schistose and fractured occurrence is generally characteristic of the metamorphites. This fractured structure makes possible the metamorphites to be hydrocarbon reservoirs. In the southern part of the Ferencszállás area and in the neighbouring Rumanian areas the gneisses are penetrated by granite pegmatite and granite porphyre veins.

The schists of Ferencszállás consist of greenish-grey *garnetiferous muscovite-biotite-mica-schists. Muscovite-mica-schist* (F—8), *biotite-mica-schist* (F—17) and *muscovitic-mica-quartzite* (F.10) also occur. These mica-schists contain considerable quantity of plagioclase. In certain boreholes zoisite and staurolite can also be determined. In the areas Ferencszállás-East and Kiszombor also the garnetiferous muscovite-biotite-mica-schist developed.

The grey *garnetiferous muscovite-biotite-gneiss* is found in a restricted area. Feldspars are represented mostly by plagioclase and to a smaller extent by microcline and albite; apatite can also be determined. The *muscovite-gneiss* was explored in the boreholes F—5. and F—12.

The metamorphites of the Ferencszállás and Kiszombor areas are continued in the neighbouring Rumanian areas. The boreholes at Cherestur and Pordenau indicate the same petrographic sequence.

The polymetamorphic rocks of Ferencszállás and Kiszombor are believed to be older than those of the Algyő area. The metamorphites formed from pelitic and psammitic sediments are assigned to the staurolite-almandine subfacies of the amphibolite facies. The rocks can be correlated with the pre-Riphean Someş—Arada series and can be identified with those of the Baia de Arieş series found in the Codru-Mountains. The idealized rock-columns of Algyő and Ferencszállás are shown in *Fig. 2*.

At Szeged, under the clastic Carboniferous two of 19 boreholes reached the crystalline basement *(Fig. 1)*. In the borehole No. 5 (between 2971 and 3027 m) two core samples explored the greenish-grey garnetiferous feldspar-bearing *biotite-gneiss,* the *chlorite-gneiss* and the *chlorite-biotite-gneiss.* Muscovite is hardly or not found. In certain strips the biotite is completely chloritized. Part of the feldspars is sericitized. The borehole No. 7. explored grey garnetiferous *chlorite-biotite-gneiss* between 3022 and 3136.5 m. In addition to the plagioclase orthoclase and epidote can also be identified.

Between Szeged and Algyő the borehole Újszentiván-2 (Uszi-2) also explored the metamorphites between 3379 and 3450 m. Here grey and greyish-green garneti-

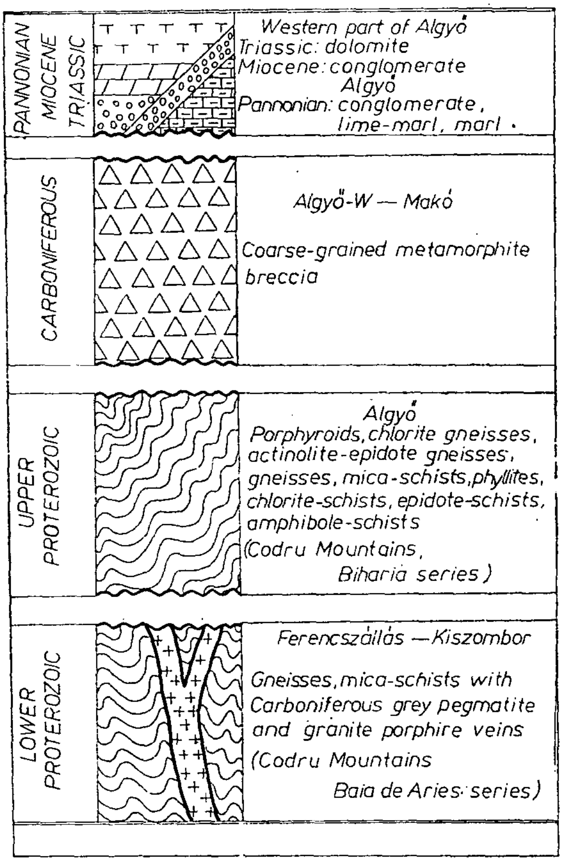

Fig. 2. Idealized rock-column of the Algyő—Ferencszállás area.

ferous chloritic *biotite-gneiss* was found. The quantity of muscovite is negligible, that of the orthoclase seems to be considerable. Talc formation can also be observed. Cordierite and staurolite occur as accessory minerals. SZALAY, Á. [1977] belives erroneously the crystalline basement of Újszentiván to be mica-schist.

In the boreholes of the Kiskundorozsma area the vertical picture of the metamorphic formations of the Southern Great Plain can be outlined since the upper part of the crystalline basement was explored in a thickness of 100 to 370 metres. Nine boreholes were drilled in this area and five of them reached the crystalline basement *(Fig. 1)*. The overlying strata are Lower Tortonian basal conglomerates. In the upper part of the basement grey and greyish-green mica-schist, in the lower part greyish-green gneiss are found. This sequence is interrupted by green amphibolite, amphibolite-schist and white quartz strata, further dark-grey dolomite and white marble strips are found in irregular position. The metamorphites of sedimentary origin are represented by *garnetiferous feldspar-bearing muscovite-biotite-mica-schist, biotite-mica-schist* and *muscovite-biotite-gneiss.*

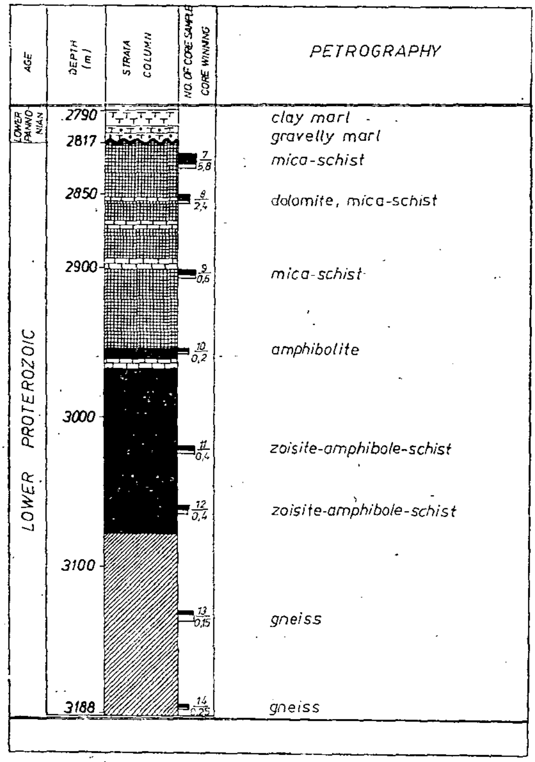

Fig. 3. Stratigraphy of the borehole Kiskundorozsma—7.

The borehole Do-1. explored mica-schist in the deepest tectonic position (between 3462 and 3480 m; separated by a fault from the other boreholes) and this rock contains zoisite, epidote and albite of new generation. In the mica-schist of the borehole No. 4 (3060—3101 m) white *crystalline limestone (marble)* is found. In the borehole No. 6. (3070 to 3147 m) *marble* is intercalated in the mica-schist and mica-quartzite strata, in the lowermost part greyish-green fine-grained *amphibolite* is found. The old metamorphites are explored in greatest thickness by the borehole No. 7. (2817—3188 m). Eight core samples were taken. Here the sequence consists of gneiss in the lower part (110 m), amphibolite and amphibole-schist (120 m) in the middle part and mica-schist of highest tectonic position. Crystalline dolomite strips occur between 2870 and 3000 m. On the basis of well logging their exact positions are 2852—2854 m, 2872—2875 m, 2889—2901 m and 2962—2967 m

(*Fig. 3*). The material of the borehole No. 8. shows the greatest variety of rocks. In addition to the gneiss, quartzites, amphibolites and marbles play also predominant role. The particular petrographic sequence is seen in *Fig. 4*, while the idelized rock-column of the Szeged—Kiskundorozsma is demonstrated in *Fig. 5*,

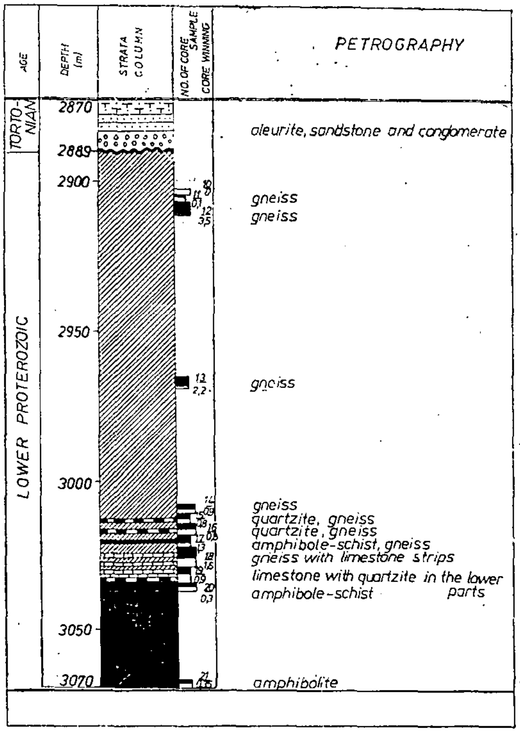

Fig. 4. Stratigraphy of the borehole Kiskundorozsma—8.

The borehole Üllés-Southeast-2 drilled west of the Kiskundorozsma area explored grey, greenish-grey garnetiferous sericitic chlorite-biotite-gneiss and muscovite-biotite-mica-schist under the Tortonian conglomerate, between 3180 and 3274 metres.

When summing up it can be stated that the material of the metamorphites of this area were terrigenous pelitic, psammitic and carbonate sediments as well as basic initial igneous products, *i.e.* mostly tuffs. The degree of metamorphism reached the staurolite subfacies of the almandine-amphibolite facies.

The stratigraphic correlation with the Rumanian and Yugoslav complexes seems to be unsolved just because of the great distance and of the missing data. The rocks are assigned to the oldest metamorphites and show some similarities with the pre-Baikalian Somes, and Baia de Aries series of the Biharia-sequence as well as with the crystalline rocks of the Serbo-Macedonian Massif.

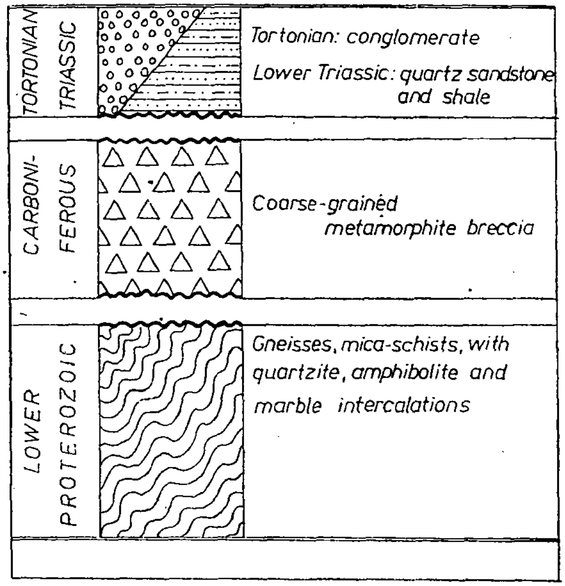

Fig. 5. Idealized rock-column of the Szeged—Kiskundorozsma area.

PALEOZOIC

The anchi-metamorphic breccias of probable Carboniferous age are believed to be younger formations and are found from Üllés to Makó. Essentially, this formation derives from the terrestrial erosion of the old metamorphites and was formed in situ. The metamorphite breccias were firstly explored by the boreholes of Szeged.

Here the grey, greenish-grey *metamorphite breccia* is underlying the Triassic shale and quartz sandstone (Tortonian conglomerate in the southern part) which was explored by 11 boreholes *(Fig. 1)*. This was totally penetrated only in the boreholes No. 5. and 7. Its thickness amounts to 268 m (2703—2971 m) in the borehole No. 5. In the coarse clastic breccia (max. 10 to 15 cm) sericitic, locally kaolinic mica-schist, gneiss, mica-quartzite, chlorite-schist and talc-schist were found. The sequence cemented by metamorphite clastics is folded and contains laminated bright sliding surfaces. In the borehole No. 7. black shale intercalation was also found the palynological investigation of which proved to be resultless.

Similar formation was explored by the borehole Üllés-SE-1. Here the Tortonian basal breccia is underlain by gneiss- and mica-quartzite-composed breccia from 3503 m down to the bottom (3703 m).

The new investigations proved that in the deeper part of the Algyő uplifted block subsided along faults the breccias of the eroded metamorphites were accumulated. In the western part, under the Tortonian strata such a kind of breccia was explored by the boreholes 14., 17., 72., 105., 106. and 107, without penetrating them. The breccia contains gneiss, mica-schist, mica-quartzite, phyllite and chlorite-schist. Farther, *i.e.* in the boreholes of Újszentiván the breccias underlying the

Lower Pannonian marls can also be found. The borehole No. 1 was stopped in the breccia consisting of mica-schist and mica-quartzite, the borehole No. 2 traversed the formation between 3298 and 3379 m and reached the Precambrian gneisses. In the southern part of the deep Neogene depression of Makó—Hódmezővásárhely the borehole Makó-2 explored grey, broken breccia-like slightly schistose gneiss and its clastics between 5010 and 5060 m underlying the Werfenian-Campilian dolomite-marl and schistose claystone. According to SZEPESHÁZY, K. [1973] these slightly metamorphized rocks formed from the fragmented old metamorphites, can be qualified as metapsephites on the basis of the Körösszegapáti and Füzesgyarmat analogies, and can be identified with the blastodetrites of Carboniferous age of the Paiuşeni Series of the Hegyes-Drócsa Mountains. As to our opinion, these breccias did not reach the degree of metamorphism characteristic of the metapsephites since they have no metamorphic structure. Their formation is assigned to the Carboniferous. This seems to be proved by the stratigraphic position of the breccia known recently in the Üllés area. In the borehole Üllés-15, between 2683 and 2767 m the breccia is overlain by Lower Triassic quartz sandstone, and underlain by Lower Paleozoic meta-conglomerate.

In the southern part of the Ferencszállás area, in the boreholes 3., 4., 91. and 35, as well as in the boreholes of Cherestur-12. and 107 *(Fig. 1)* grey, often compressed pegmatite and granite porphyre veins are known. The *pegmatite* is of porphyroblastic texture and contains microcline. Its mineral constituents are plagioclase (mostly oligoclase), microcline, quartz and muscovite. The *granite porphyry* (boreholes 3. and 4.) has porphyric texture, fine-grained and microclinic. Its mineral components are mostly potash feldspar (microcline and orthoclase), plagioclase (albite and oligoclase), quartz, muscovite and biotite. Albite occurs in lenticular forms.

These veins penetrating the metamorphites are believed to be the products of the second-step [Carboniferous] granitization. Similarly to the Mecsek Mountains [JANTSKY, B., 1974, SZEDERKÉNYI, T., 1974] the investigations of the Mezőhegyes—Battonya [T. KOVÁCS, G. — KURUCZ, B., 1978] show that the first Precambrian granitization was followed by a second Carboniferous anatexis, and vein formation. The metamorp hites of the southern part of the Pusztaföldvár area are penetrated also by Carboniferous aplite and graenit-porphyre veins. Just because of the fact mentioned above the statements of SZALAY, Á. [1977] cannot be accepted, *i.e.* "the light-grey granites of metasomatic formation are known in the narrow zone lying in direction of Kiszombor—Ferencszállás—Algyő—Szeged— Kiskundorozsma". As to our opinion the evidences of the metasomatic granite formation are missing. As it was mentioned earlier, the formation of the Algyő (Deszk) porphyroids is Precambrian, thus it cannot be contemporaneous with the granite veins of Ferencszállás. The lack of the migmatite zone is caused not by the metasomatic formation but rather by the vein-like development. It is illusory to assume a belt-like appearance of granite since neither in the Kiszombor nor in the Szeged—Kiskundorozsma area any kind of granite (nor igneous rocks) was found in the boreholes.

In the area investigated other formations which could be assigned to the Paleozoic cannot be found. Sedimentation started only in the Lower Triassic.

REFERENCES

BALOGH, K. — KŐRÖSSY, L. [1974]: Tectonics of the Carpathian Balkan Regions. Explanation to the tectonic map of the Carpathian-Balkan regions and their foreland. — Geol. Inst. „D. Stur" p. 391—393. Bratislava.

BLEAHU, M. [1974]: The Apuseni Mountains. — Tectonics of the Carpathian-Balkan Regions. Bratislava, p. 221—240.
BONCEV, E. [1967]: Das Kraistiden Problem. — Symp. über die Problemen der Kraist. Sofia Nr. 1. p. 1—16.
JANTSKY, B. [1974]: A mecseki kristályos alaphegység földtana (Geology of the Mecsek Crystalline Basment). — Thesis for D. Sc. MTA-Library.
JUHÁSZ, Á. [1969]: A Duna—Tisza köze mélységi magmás és metamorf képződményei (Deep igneous and metamorphic formations of the Danube—Tisza—Interfluve). — Földtani Közl., *99*, p. 320—336.
T. KOVÁCS, G. [1976]: A Szeged alatti szénhidrogén-kutatás geofizikai, geológiai lehetőségei, problémái és eredményei (Possibilities, problems and results of the geophysical-geological hydrocarbon exploration under Szeged). — Kőolaj és Földgáz *109*, p. 193—197.
T. KOVÁCS, G. [1975]: A Duna—Tisza köze déli részének miocén képződményei (Miocene formations of the southern part of the Danube-Tisza-Interfluve). — Földtani Közl., *105*, p. 220—236.
T. KOVÁCS, G.—KURUCZ, B. [1978]: A Dél-Alföld prekambriumi és paleozóos képződményei (Precambrian and Paleozoic formations of the Southern Great Plain). — Szeged, manuscript.
RÓNAI, A.—SZEPESHÁZY, K. *et al.* [1974]: Magyarázó Magyarország 200 000-es földtani térképsorozatához. L-34-XV Szeged és L-34-XVI Gyula (Legend to the geological map series of Hungary of 1:200.000 scale). MÁFI, Budapest.
SOMFAI, A. [1968]: Az algyői szénhidrogéntároló szerkezet földtani felépítése (Geological built-up of the hydrocarbon-bearing structure of Algyő). — Szeged, manuscript.
SZALAY, Á. [1969]: A szegedi medence metamorf kristályos képződményeinek ásványkőzettani, geokémiai feldolgozása (Mineralogical-petrological and geochemical evaluation of the metamorphic crystalline formations of the Szeged Basin). NKFÜ, report.
SZALAY, Á. [1977]: Metamorhpic-granitogenic rocks of the basement complex of the Great Hungarian Plain, Eastern Hungary. — Acta Miner. —Petr., Szeged, *XXIII/1*, p. 49—69.
SZÁDECZKY—KARDOSS, E. — BUBICS, I. *et al.* [1967]: Metamorphose in Ungarn. — Acta Geol. Acad. Sci. Hung., *11*, 1—3, Budapest, p. 49—58.
SZÁDECZKY—KARDOSS, E. — JUHÁSZ, Á.—BALÁZS, E. [1969]: Erläuterung zur Karte der Metamorphite von Ungarn. Acta Geol. Acad. Sci. Hung., *13*, Budapest, p· 27—34.
SZEDERKÉNYI, T. [1974]: A délkelet-dunántúli ópaleozóos képződmények ritkaelem kutatása (Trace element investigations in the Early Paleozoic formations of SE-Transdanubia). — Theses for CSc. MTA-Library.
SZEDERKÉNYI, T. [1977]: Geological evolution of South Transdanubia (Hungary) in Paleozoic time. — Acta Miner. — Petr., Szeged, *XXIII/1*, p. 3—15.
SZEPESHÁZY, K. [1966]: A kristályos aljzat fontosabb típusai a Duna—Tisza köze középső és déli részén (Some important types of the crystalline basement in the central and southern part of the Danube—Tisza—Interfluve). — MÁFI Évi Jel. 1966 évről, p. 257—265.
SZEPESHÁZY, K. [1973]: A Kárpátok és az Alföld metamorf képződményeinek kapcsolatai (Relations between the metamorphic formations of Carpathians and of the Great Plain). — Ált. Földtani Szemle *3*, p. 5—58.
VÖLGYI, L. — BANLA, K. — SUBA, S. —CSALAGOVICS, I. [1970]: Magyarország szénhidrogén telepei (Hydrocarbon beds of Hungary). — Algyő, OKGT, Budapest.

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THE SARMATIAN FORMATIONS IN THE TISZÁNTÚL AREA [EAST HUNGARY] AND THEIR STRATIGRAPHIC POSITION

K. SZENTGYÖRGYI

ABSTRACT

In the hydrocarbon prospecting area of Tiszántul Upper Miocene formations have been hit by more than houndred bores. The sediments of the Sarmatian stage correspond to the time interval between the Badenian and Pannonian ages. The stage is biostratigraphically bipartite (Kozardian and Tinnyean substages). In the Tiszántúl area the Sarmatian formations are overlying the Badenian rocks, transgressively near the shore and comformably in the inferior of the basin. They are overlain, on their turn, by different lithostratigraphic members of Pannonian stage. There is a stratigraphic gap of varying importance and at some places a slight angular unconformity to be observed between the Sarmatian and Pannonian stages.

The transgressive basal beds of the Kozardian substage are usually overlain by littoral Miliolina limestone. The brackish water Kozardian sediments pass gradually, without any trace of interrupted sedimentation, into the mostly carbonatic sequence of the Tinnyean substage. The formations of this younger substage, however, are missing in the major part of the area, due to erosion, or they are known in some isolated occurrences only.

The sediments of the Sarmatian stage are characterized by a brackish water microfauna consisting of a few taxons represented by numerous specimens. Towards the end of Kozardian substage about the half of the forams have become extinct.

The Upper Miocene sediments explored in the Tiszántul area have been deposited in a shallow-water basin of rather complicated shore-line. In the northern part of the area and in the Nyirség at the same time the continental sequence of rhyolitic volcanic formations came into being.

The Sarmatian sediments disclosed by hydrocarbon drilling can be correlated biostratigraphically with the sediments of the surrounding basin areas, while the lithostratigraphic units can be traced for short distances only even within the Tiszántul area.

INTRODUCTION

During hydrocarbon exploration Upper Miocene formations were hit in several boreholes of the Hungarian Plain, more exactly, in the Tiszántúl area. The stratigraphic position of these sediments and their relathionship as to the much better known geological profiles of the mountain margins have been scarcely studied so far.

The type section of the Sarmatian stage was originally described by BARBOT DE MARNY, N. in the surroundings of Kherson. The stratigraphically tripartite character of the stage was established by ANDRUSOV, N. [1899]. SIMIONESCU, J. [1903] proposed the denominations of the Volhynian, Bessarabian and Khersonian substages. At present, in the type region (East Europe) the Sarmatian stage is subdivided into three substages (the Volhynian, Bessarabian and Khersonian ones) and six horizons [KOJUMDGIEWA, E. 1971]. In the area of the Central Paratethys (in its presentday sense) SUESS, E. [1866] was the first distinguish Sarmatian sediments in the Neogene sequences of Austria. He ranged into the Sarmatian the "Cerithium Beds" comprised between the "Baden Clay" and the "Congeria Beds".

It soon became evident, that the Sarmatian formations do not represent the same time interval in the Euxine-Caspian Basian and in the Carpathian Basin.

In the latter, only some part of the stage has been developed if compared to the Sarmatian stage as developed in South-Eastern Europe. In another, but not very exact formulation this means that the Sarmatian formations of Eastern and of the Central Paratethys correspond only partly to each other: in large areas of the Central Paratethys a considerable part of the Sarmatian sediments of Southern Russia is represented by the Pannonian sediments.

The difficulties arising in the correlation of the Sarmatian stage are essentially due to the fact, that *during the Bessarabian the intracarpathian basins of the Central Paratethys became isolated from the Eastern Paratethys* and mostly of each other, too.

Relying upon the investigation into the Sarmatian outcrops in Hungary, SCHRÉTER, Z. [1912, 1941] stated that their fauna is identical to that of the Volhynian substage in Southern Ukraina. Even the more recent studies could produce only a few forms characteristic of the Bessarabian substage (BODA, J. 1959]. However, the vertebrate studies suggested that the Sarmatian formations in Hungary should comprise at least some part of the Bessarabian substage [KRETZOI, M., 1961]. Finally it could be established by BODA, J. [1971, 1974] by means of molluscs and by KŐVÁRY, J. [1973] as regards the microfauna that the Sarmatian sequence in Hungary is biostratigraphically bipartite: *the Kozardian substage corresponds to the Volhynian one while the Tinnyean substage to the lower part of the Bessarabian substage* [BODA, J., 1974]. *If speaking about Sarmatian in Hungary, the time interval comprised between the end of the deposition of the Badenian formations and the beginning of the deposition of the Early Pannonian sediments.*

The investigation of the Sarmatian formations in Hungary was not extended, for a long time, to the interior of the basins, due to the fact that they were not disclosed. The better understanding of the geology of the deeper parts of the Great Plain, comprising also the Tiszántúl area, is closely linked up with hydrocarbon prospecting. Between the two World Wars, a few boreholes were drilled financed by the State Treasury. These were improductive from the point of view of oil geology, but they enhanced considerably our knowledge about the deeper part of the Great Plain [SCHMIDT, E. R., 1939]. The first boreholes to hit Sarmatian formations in the Tiszántúl area were Hajdúszoboszló-II., Debrecen-I. and Tisztaberek-1.

After World War II the oil and gas industry having been nationalized, its methods changed and its dimensions were considerably enlarged. Hydrocarbon prospecting became an industrial-scale activity. This lead to the better knowledge of individual areas, notwithstanding the only partial (periodical) core drilling generally used. Rapid development in geophysical well-logging methods contributed undoubtedly to the clearing up of the position of the drilled formations.

During the past three decades, Upper Miocene formations were discovered in 30 prospecting areas of the Tiszántúl. The results of hydrocarbon prospecting in this region were summed up by KŐRÖSSY, L. [1956]. He pointed out that the Sarmatian sediments at some places are overlying unconformably and transgressively the older rocks and established that they represent the Volhynian substage of East Europe. Analyzing the subsurface geological setting of the central part of the Great Plain, VÖLGYI, L. [1965] draw the conclusion that the Lower Pannonian limy marl and the Sarmatian limy marl are synchronous facies, but this assumption was not supported by any biostratigraphic evidence. Even the microbiofacies studies resulted only in producing a possibility of distinguishing the fossil assemblages of the Badenian and the Sarmatian. Neither the foraminifers, nor the ostracods permitted the reliable subdivision of the Sarmatian sediments. Consequently, lacking the help of biostratigraphy, and due to the difficulties of lithostratigraphic subdivision, as concerns the Sarmatian sequence of the Tiszántúl area it could be stated only that theys it represents the older portion of the stage, but the interrelation of the sequences in different parts of the area remained an unsettled problem [SZÉLES, M., 1970, SZEPESHÁZY, K., 1971].

LITHOSTRATIGRAPHY

1. Extent and bedrock

Upper Miocene (Sarmatian) formations are known in several hydrocarbon prospecting areas of the Tiszántúl region, being of the largest extension in the central and northeastern parts *(Fig. 1.)*. Their being hit by a few drillings only causes difficulties in the paleogeographic reconstruction.

The brackish-water Sarmatian sediments overly unconfomably partly Badenian, partly more ancient rocks.

Sarmatian sediments overlying *transgressively* the Lower Paleozoic basement is known at Csanádapáca, Körösszegapáti, Sarkadkeresztúr, Füzesgyarmat as well as south of Nagyvárad (Oradea). The Upper Miocene is underlain by Triassic in the borehole Magyardombegyháza-1, by Jurassic in borehole Hajdúszoboszló-II by Cretaceous in borehole Kunmadaras-8. Along the Senonian-Paleogene flysch trough of the Tiszántúl region the Sarmatian sequence lies upon flysch sediments (borehole Turgony-1, Ebes-7, Hajdúszoboszló-3, Hajdúszoboszló-5, Hajdúszoboszló-17), as well as in the NE prolongation the Flysch belt in the vicinity of Scarisoara Noua and Piscolt. The distribution of the locally transgressive Sarmatian sediments is essentially the same as that of the Badenian ones.

The Badenian sedimentary basin, being rich in islands, was added to by several portions of the dry land, while at other places the Sarmatian sediments lie transgressively. In many cases it is difficult to decide whether the lack of Sarmatian sediments is primary or due to removal at the Miocene-Pliocene boundary. The immediate bedrock is of *Badenian* age in boreholes Csanádalberti-1., Szandaszöllős-10. and one part of the boreholes in the Kisújszállás, Püspökladány, Furta-Zsáka, Nádudvar, Komádi, Kaba, Ebes and Hajdúszoboszló. In the most cases the Sarmatian formations are underlain by Badenian marine deposits in the Nagyvárad—Szatmárnémeti (Oradea-Satu Mare) basin. Rhyolite and rhyodacite tuffs of badenian age overlain by Sarmatian sediments in boreholes of Hajdúnánás, Balmazújváros, Debrecen, Nagyiván and Tatárülés. The stratigraphic subdivision of the mighty neovolcanic sequence in the Tiszántúl region is still an unsolved problem. These series consisting mostly of pyroclastites comprise very likely the combined time interval of the Badenian and Sarmatian ages (at Komoró, Hajdúhadház, Nyírmártonfalva, Hajdúböszörmény, Nagyecsed). At some places the undivided volcanic sequence is overlain by the brackish water sedimente of the Late Sarmatian (Tinnyean) substage. In such cases the volcanic formations correspond to the time interval of the Badenian—Kozardian (e.g. at Nyíregyháza, Nyírlugos, Tisztaberek).

It is rather difficult to draw the contours of dry land in the Sarmatian sedimentary basin. This due to the rather unequal grad of exploration as well as to erosion.

The southern and southeastern margin of the basin can be traced (relying upon the presence of transgressive littoral sediments), the position of the islands, however can not be established, with the exception of the Nyírség volcanic ridges.

The contact of the Badenian and Sarmatian sediments is directly known in a few profiles only. Usually, in cases of continuous core drilling, a gradual transition can be stated. In the Szandaszőlős borehole (Sza-10.) the Badenian-Sarmatian boundary is at a depth of 1812 m. The Upper Badenian is made up by compact, sandy Lithothamnian limestone. This rock contains a rich assemblage of benthic foraminifers *(Asterigerina planorbis* D'ORB., *Anomalina simplex* D'ORB., *Borelis melo* FICHT.—MOLL., *Elphidium crispum* LINNE). This passes gradually into a compact

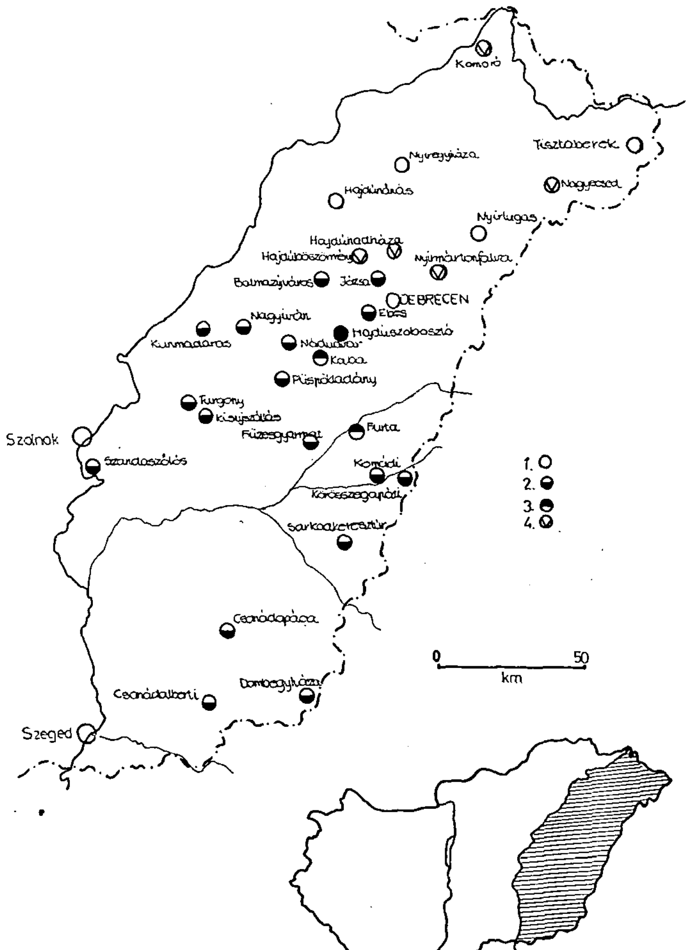

Fig. 1. Occurrences of Sarmatian formations in the Tiszántúl region

Legend

1. The Kozárdian substage is made up by continental volcanites, the Tinnyeian substage by brackish water sediments
2. Brackish water sediments of the Kozardian substage
3. Brackish water sediments of the Tinnyeian substage
4. Sarmatian represented by continental volcanites

Miliolina limestone with thin intercalations of limy marl, assigned to the Kozárdian substage. In the Püspökladány area the gravely *Lithothamnian* and *Amphistegina* bearing limestone of the Badenian passes without interruption into the equally gravely *Miliolina* limestone of the Kozárdian substage (borehole Pü-4.). In this material KŐVÁRY J. found *Cibicides lobatulus* WALK.—JAC., *Triloculina consobrina var. sarmatica* GERKE, *Elphidium macellum* FICHT.—MOLL, *Bolivina sp.* and *bryozoans.* Without any sign of interrupted sedimentation develops the Upper Miocene from the littoral Badenian in the lithologic column of boreholes Józsa-2 and Kisújszállás-1. In the Nádudvar are (borehole Nu-10.) the transition is known to occur in a more off-shore facies. Here, Lower Badenian rhyolite tuff is overlain by *Orbulina* marls, the Upper Badenian being represented by limy marls with *Lithothamnium* nodules. In the lower portion of this marl series marine foraminifers are still common, whereas in the upper one the brackish water *Miliolina* are predominating, accompanied by *Cibicides lobatulus* WALK.—JAC.

Thanks for lucky core sampling, in some boreholes of the Tiszántúl region the presence of Kozárdian beds overlying *transgressively* Badenian sediments could also be established. In borehole Csanádalberti-1 the Badenian silty, plancton foraminifera bearing marls are overlain by limy microconglomerate beds with rounded *Lithothamnium* nodules, incrusted *Pyrgo sp.* and *Miliolina* specimens. This transgressive conglomerate with redeposited Badenian microfossils of 11 m thickness passes into a 43 m mighty Kozárdian conglomerate characterized by the presence of persistent marine foraminifers only *(Anomalina sp., Bolivina sp., Nonion depressulum* WALK.—JAC., *Elphidium antoninum* D'ORB., *Elphidium aculeatum* D'ORB., *Elphidium crispum* LINNE, *Dendritina sp., Cibicides lobatulus* WALK.—JAC.).

The relationship existing between the sediments of the two stages could not be established with certainty in borehole Komádi-8. The sample taken from the depth interval 2008—2020,5 m was an *Orbulina* and *Globigerina* bearing siltite, while the next one upwards (between 1992 and 2000 m) was already a marly siltite with *Articulina* and *Miliolina,* belonging to the older substage of the Sarmatian. The 8 m metres between the to cores reveal no significant change in the lithology according to geophysical well logging, so their belonging to the Upper Badenian can not be ascertained.

At the boundary of the central and the northeastern parts of the Tiszántúl region, volcanic formations are widespread in the sequences. If there are Upper Badenian "Leithakalk" beds intercalated among the tuffs, the Badenian/Sarmatian boundary is easy to trace (boreholes Kaba-É-3, Balmazújváros-1). However, the neovolcanic sequence of the North Tiszántúl could not be subdivided from the stratigraphic point of view so far. It can be assumed that the mostly tuffitic formations may comprise a considerable part, at places eventually the totality of the Sarmatian.

Similar problems exist as to the position and even to the presence of the Sarmatian formations in the area of the deep depressions of the Tiszántúl region (Hódmezővásárhely—Makó graben, Békés-Depression). From the boreholes drilled in these areas, from the interval of over 100 m comprised between the faunistically proved Badenian and Lower Pannonian beds no core has been recovered. As due to the great depths, drilling technological difficulties affect the quality of lithological information rather negatively, deduced from geophysical well logging. In borehole Makó-2 a sample was taken from 4570 m depth. The conglomerate and marl pieces contain *Elphidium crispum* LINNE and fragments of the algal genus *Lithoporella* suggesting the presence of the Sarmatian. No stratigraphic evidence has been produced by the boreholes at Hódmezővásárhely, Hunya and Kondoros, which would permit to draw conclusions as to the presence or absence of the Sarmatian stage. It should not be disregarded, however, that along the margin of these deep depressions at least the Lower Sarmatian is developed in form of littoral sediments, and that according to our present-day knowledge these depressions were subsiding continuously from the beginning of the Badenian age on. It seems to be rather unlikely that during the Sarmatian no sedimentation should have occured.

2. Formations of the Kozárdian substage

The Kozárdian substage is represented by *brackish water sediments* in the southern, southeastern and central parts of the Tiszántúl region and by mostly *volcanic formations* in the northern one *(Fig. 2)*. The brackish water series are seldom more than 50 m thick, while the volcanic formations may be several times thicker. The complete thickness of the sedimentary sequence of the Kozárdian substage is, in fact, reliably known in the surroundings of Hajdúszoboszló only, where it is 40 to 60 m.

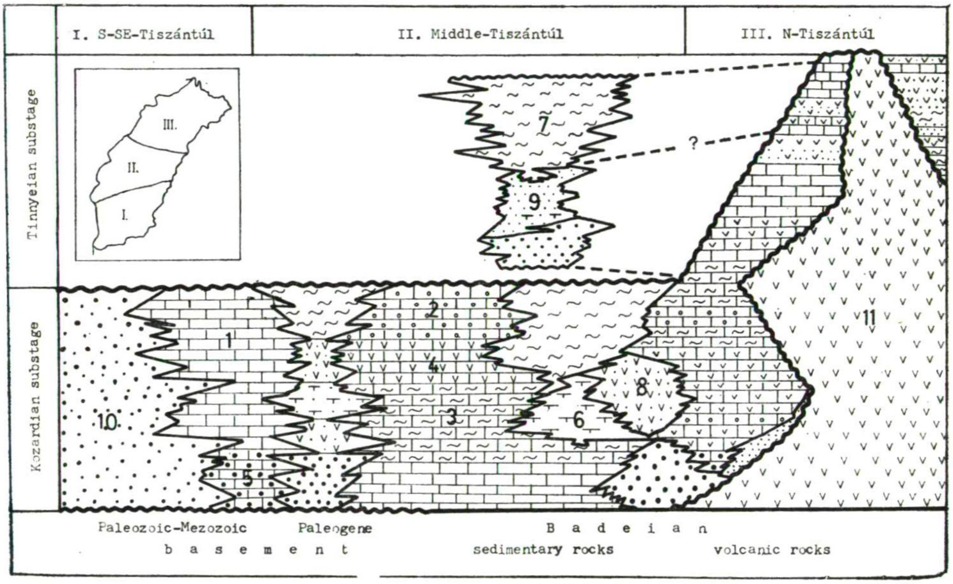

Fig. 2. Interrelations of the lithological units of the Sarmatian in the Tiszántúl region (Strongly distored)

Legend

1. Compact, unstratified limestone
2. Ooidic limestone
3. Marly limestone
4. Tufaceous limestone
5. Gravely limestone
6. Marl, limy marl
7. Clayey marl
8. Tufaceous sandstone, tuffite
9. Limy sandstone
10. Conglomerate
11. Continental volcanite

The sediments of this older substage are mostly of littoral facies. Off-shore formations are rare and of limited extension.

The marginal, *transgressive sequences* of the sedimentary basin consist often exclusively of conglomerates (at Csanádalberti), at some places, however, their are bipartite. The *lower* member is a basal conglomerate and the *upper* one a littoral Miliolina limestone (at Csanádapáca, Magyardombegyháza, Sarkadkeresztur). The third type of the along-shore series is represented by transgressive *Miliolina* limestone (at Körösszegapáti) with thickness data but rarely exceeding 30 m. This is the case in the are disclosed between Arad and Nagyvárad (Oradea) (at Socodor, Salonta, Chisineu Cris).

The sequences intersected in the central part of Tiszántúl area are characterized by a more varied lithology. A mostly detrital and a predominantly carbonatic facies can be distinguished, without being neatly separated (with interfingering).

The clastic sequences consist usually of a lower conglomerate and an upper sandstone member. The uppermost known member is mostly marl or clay marl. A typical profile has been drilled at Füzesgyarmat (borehole Fü-6.). The Upper Miocene sequence overlies with a transgressive basal conglomerate the brecciated surface of the crystalline basement. This conglomerate passes gradually into gravely sandstone and sandstone. The sequence is closed with a brackish water *Miliolina* and *Elphidium* bearing marl member.

In the Püspökladány area the basal conglomerate is substituted by littoral limestone. This *Articulina* and *Miliolina* bearing limestone is overlain by a sandstone member with thin intercalations of conglomerate. The series representing the Kozárdian substage in borehole Kisújszállás-1 consists, in a similar way, of mostly tuffitic sandstone and sandy tuffite, the marl become the predominant lithologic type in the uppermost member only.

The clastic sequences are found relatively rarely in the Tiszántúl area. The lithology of *the early Sarmatian formations is overwhelmingly carbonatic.* However, the purely carbonatic sequences are but rarely homogeneous. Lithostratigraphic correlation is made difficult by the lithologic variations of the limestones as well as by interfingering and intercalation of detrital sediments.

The most part of the Kozárdian limestones are of biogenic origin, they contain masses of *Miliolina* tests. The compactness and the degree of diagenesis is rather variable, all varieties occur from the easily friable sediment to the hard, compact, calcite-veined limestone. The bioclasts are embedded in a micritic matrix of widely varying amount. The limestones contain considerable allotigenic clastic material, gravel, tuff and often clay. Gravely limestone is characteristic first of all of the beds of deeper lithostratigraphic position. This type of rock is particularly common in places where the Kozárdian develops from *Lithothamnian* limestone. In the same areas also the clayey limestone type is common, representing a transition between the littoral limestones and the off-shore pelitic sediments. It is remarkable that sandstone members of large extension have not been found even in the fairly well explored areas. Rock types earlier described as calcarenites turned out to be ooidic limestones or sandy limestones.

A typical lithological variety, which is, however, not exclusively characteristic, of the Kozárdian substage, is the *ooidic facies,* widespread in the areas of Ebes Hajdúszoboszló, Kaba and Nagyiván. The nucleus of the ooids in the regionally scarcely varying ooidic limestones consists usually of volcanic quartz grains or *Miliolina* tests. They are embedded in a clayey, micritic carbonate matrix. The hardness of the rock depends of the amount and eventually of the nature of the embedding material. No system could be establishes as to the occurrence of the ooidic beds in the mostly limestone sequences. The only certainty is that this rock type has been formed in shallow and periodically agitated water.

In the boundary zone of the central and northern parts of the Tiszántúl area the rhyolite tuffs beds became ever thicker and more numerous as going towards the continental eruption centres. Within the carbonate sequences, they interfinger with the brackish water sediments in a zone at present poorly explored. Notwithstanding the relatively low degree of exploration, it seems probable that in this area the Kozardian substage should be represented by *continental pyroclastites.*

A sedimentation differing considerably from that of the other areas of the Tiszántúl region occurred in the depression between Nagyvárad (Oradea) and Szatmárnémeti (Satu Mare) [ISTOCESCU, D.—IONESCU, G., 1968]. There, the early Sarmatian sediments are developed in a thickness of 100 to 300 m. The sequences are characterized by an alternation of sandstones, limestones and conglomerates. The individual lithostratigraphic member can be traced to longer distance. In the surroundings of Szatmárnémeti (Satu Mare) the rhyolite tuffs became more numerous, growing to a continuous, independent member at the Hungarian frontier. Most likely also in this area in interfingering of the brackish water sediments with the rhyolite tuff series can be established.

3. Formations of the Tinnyeian substage

The later Sarmatian formations are completely *missing in the sequences of the South Tiszántúl area.* Some isolated occurrences of the Tinnyeian substage are known from the central part of the Tiszántúl region. Their continuous, regional extension is, however, characteristic of the northern Tiszántúl. Two isolated occurrences of the substage are the boreholes Furta-2 and Kaba-5 in the central part of the Tiszántúl region. In both boreholes, the Tinnyeian formations overlye transgressively the Lithothamnian, gravely limestone, and the limy conglomerate of the Upper Badenian, respectively. A basal conglomerate grades insensibly into a poorly fossiliferous sandstone, overlain by siltite in the Furta—Zsáka borehole and by clay marl in the Kaba borehole.

Mostly carbonatic sediments compose the sequence of the Tinnyeian substage in the Hajdúszoboszló boreholes. Where drilled with core, a continuous lithological transition could be observed (boreholes Hsz-6., -13., -30.). Passing towards the upper members, the percentage of detrital materials is increasing. (Fine sandy intercalations, more frequent appearance of marly limestone beds.) The ooidic limestone beds become ever rarer. If compared to the limestones of the Kozárdian substage, it is an important lithologic difference, that *no Miliolina limestone occurs in the Tinnyeian.* The end of the rock forming importance of Miliolina does not mean, however, that the biogenic factors of sedimentation became completely subordinate. The tests of other foraminifers and the shells of molluscs play a considerable role in the composition of the limestones. The sediments of this substage are more easy to subdivide lithologically and much less diagenetized, than those of the early Sarmatian. Intercalated marls occur more often, but gravely limestones are very rare.

In the northern part of the Tiszántúl region the brackish water *sediments of the Tinnyeian substage lie transgressively* over the rhyolite tuffs formed in in the Kozárdian or Badenian. In the boreholes of Hajdúnánás, Nyíregyháza, Nyírlugos, Debrecen and Tisztaberek rhyolite and rhyodacite tuffs alternate with beds of limy marl, limestone, tuffitic sandstone and tuffite. In this area, the brackish water sediments display an extraordinary lithologic variability. Due to this fact and to the rather low degree of exploration, no lithostratigraphic correlation can be made. The sequences in the northern part of the Tiszántúl region are relatively mighty, exceeding 100 m, in consequence of the intercalated pyroclastic members, while in the other areas, the late Sarmatian brackish water sediment series have thicknesses below 40 m.

It is difficult to judge the completeness of the Tinnyeian sequences, because they are overlain by Pannonian sediments with a considerable stratigraphic hiatus. It is probable that the surface of the Sarmatian has been modelled by erosion. It is difficult to say, however, how much has been removed by erosion. It is an une settled question the later Sarmatian formations are present in the deep Neogen- depressions. At present it is assumed that the entire Upper Miocene is present, without being disclosed, below the mighty Pliocene cover.

4. *The Post-Sarmatian Cover*

The Sarmatian formations of the Tiszántúl region are covered by Lower Pannonian, in some cases by Upper Pannonian sediments of varying thickness. They are of *greatest thickness, and represented by oldest members, in the area of the deep Neogene depressions,* while they are rather thin and young in the northern part of Tiszántúl. In this latter area, the Sarmatian is directly overlain by Upper Pannonian sediments, the Lower Pannonian is completely missing.

The discussion on the stratigraphic subdivision and biostratigraphy of the Pannonian sediments of the basin is still going on. In this paper this discussion should not be outlined. None the less the stratigraphic position of the Pannonian sediments is in close connexion with that of the Upper Miocene formations. Széles, M. [1971] succeeded in establishing that the Pannonian formations of the Hungarian Plain can be considered biostratigraphically complete at most in the area of the deep depressions only. New points of view and unpublished evidence contributing to a lithostratigraphic model seem to support the biostratigraphic subdivisions.

The molluscs found in the cover of the Sarmatian in the Tiszántúl region prove nothing more than the presence of the Lower Pannonian *horizon of Paradacna abichi* R. H., *Congeria banatica* R. H. In most cases, however, the *erosional unconformity* existing between the Upper Miocene and the Pliocene is testified to not as much by the truncated Lower Pannonian series, as by the lack of the Tinnyeian substage. The stratigraphic gap and unconformity are obvious, in a similar way, in most part of the northern Tiszántúl. The nature of the boundary (contact) between the Upper Miocene and the Pliocene is unknown, can be only hypothetically assumed in the case of the deep depressions of the Tiszántúl region.

BIOSTRATIGRAPHY

1. *Character and Elements of the Fauna*

The biostratigraphic subdivision of the Sarmatian formations of the Tiszántúl region, known only from drill core materials, is based entirely on *microbiofacies analysis*. The macrofauna is rare and do not allow statistical studies, it is good for no more than to ascertain the presence of the stage. The Sarmatian sediments are characterized by their being of brackis water facies. At the Late Badenian/Sarmatian boundary, as a consequence of the decrease in salinity of the sea water, the composition of the foraminiferal and molluscan assemblages changed considerably.

While in the marine sediments of Badenian age in the Tiszántúl region 130 species of 50 foraminiferal genera has been found, only *50 species* belonging to *17 genera* could be discovered in the Sarmatian sediments [KŐVÁRY, J., 1973].

At the beginning of the Late Badenian salinity started to decrease in the Central Paratethys sedimentary basin, resulting in the rapid extinction of planctonic foraminifers. During the Late Badenian, the stenohaline bentonic forms became also subordinate. On the contrary, the highly adaptable euryhaline taxa abounded. At the Late Badenian/Sarmatian boundary the microbiofacies consist mostly of brackish water benthic forms, accompanied by a few specimens of persistent stenohaline species.

At the beginning of the Sarmatian a brackish water microfauna consisting of but a few species, but of pullulating specimens, became widespread. Its elements belong to the families *Anomalinidae, Miliolidae, Ophthalmidiidae, Nonionidae* and *Rotalidae*. The genus *Elphidiums* is represented by 14 species, the genus *Quinqueloculina* by 11 species and the genus *Triloculina* by 6 species.

In the borehole columns the core samples taken only at some intervals and being of small amount do not make possible to use the *molluscan faunas* for subdivision. In the case of some specias it seems to be likely that they are restricted, in the Tiszántúl region too, to one or to the other of the substage. However, with regard to the rare and rather accidental occurrence of these species further observations are needed to evaluate their biostratigraphic value. The most molluscs occur in the sediments of both substages, so their presence allows no more than to conclude as to the Sarmatian age of the sediments in question.

From the Sarmatian sediments of the Tiszántúl area SZÉLES, M. has determined the following molluscs:

Lamellibranchiata

Modiolus incrassatus D'ORBIGNY
Musculus sarmaticus GATNEV
Cardium latisulcatum MÜNSTER
Cardium vindobonense PARTSCH
Cardium praefischerianum KOLES.
Cardium subcarpathicum MERKLIN
Cardium plicatofittoni SINZOW
Irus gregarius PARTSCH
Irus vitalinus D'ORBIGNY
Ervilia dissita EICHWALD
Mactra vitaliana eichwaldi LASK.
Donax dentiger EICHWALD
Donax hoernesi LINDBERG
Abra reflexa EICHWALD

Gastropoda

Hydrobia lineata JEKELIUS
Hydrobia ventrosa FRAUENFELD
Hydrobia frauenfeldi M. HOERNES
Calliostoma angulata EICHWALD
Calliostoma papilla EICHWALD
Gibbula hoernesi JEKELIUS
Rissoa inflata sarmatica FRIEDB.

Pirenella picta DEFR.
Pirenella picta mitralis EICHW.
Cerithium rubiginosum EICHWALD
Gyraulus pavlovici BRUSINA

Up to date, 24 species of *ostracods* are known from the Upper Miocene sediments of the Tiszántúl region. SZÉLES, M. [1958, 1959] described a total of 33 species from the Sarmatian of Hungary; most of these have been found in the area of study, too. The ostracods in the sediments of the Badenian stage are subordinate elements of the faunal assemblage. Only a few families occur. Some of the species died out at the Badenian/Sarmatian boundary, but most of them went on living in the Late Miocene as well. The Sarmatian ostracod fauna is of extreme adaptability, most of its species occur also in the pliohaline formations of the Pannonian stage. The stratigraphic value of the Sarmatian ostracod species needs further investigations, because the data vailable at present refer only to one part of the basin and do not derive from a systematic collecting activity. SZÉLES, M. described the following ostracod species from the formations in the area of study:

Ostracods

Cytheridea punctillata BRADY
Cytheridea elongata BRADY
Cytheridea mülleri BOSQUET
Cytheridea hungarica ZALÁNYI
Cythereis speyeri BRADY
Cythereis fischeri M. SARS.
Hemicytheria convexa BAIRD
Hemicytheria cicatricosa REUSS
Ciamocytheridea leptostigma REUSS
Ciamocytheridea leptostigma foreolata KOLLMANN
Cyprideis punctillata BRADY
Cyprideis perangusta ZALÁNYI
Eucythere declivis MÜLLER
Miocyprideis janoscheki KOLLMANN
Haplocytheridea dacica HÉJJAS
Pontocypris declivis MÜLLER
Pontocythere perangusta ZALÁNYI
Pontocythere elongata BRADY
Loxoconcha rhombovalis POKORNY
Loxoconcha subovata MÜLLER
Cnestocythere lamellicosta TRIEBEL
Candona trapezoidea ZALÁNYI

Characteristical elements of the biofacies of the Sarmatian limestones are the *bryozoans,* which occur mostly in the littoral sediments of the Kozárdian substage. In pelitic sediments of lagoons the calcite ovoid of the species *Sphaeridia moldavica* MAC.—PAGH. (statolite after VOICU, M.) is common. The Lithothamnium are substituted by the algal genera *Lithoporella* and *Chalmasia.* In the marls, *Acicularia* are common to occur.

2. Biostratigraphic subdivision

The biostratigraphic subdivision of the Sarmatian sediments in the Tiszántúl region is based first all on the foraminiferal microbiofacies. The vertical extension of some foraminifer species is restricted to the *Kozárdian substage,* e.g. *Cibicides lobatulus* WALK.—JAC., *Elphidium reginum* D'ORB., *Elphidium josephinum* D'ORB., *Elphidium imperatrix* BRADY, *Quinqueloculina pauperata* D'ORB., *Quinqueloculina bronniana* D'ORB., *Quinqueloculina reussi* BOGD., *Triloculina inflata* D'ORB., as well as the species of the genera *Articulina* and *Dendritina* (Table 1.). The following species occur rarely, but up to now only in the sediments of the Kozárdian substage: *Triloculina scapha* D'ORB., *Quinqueloculina haidingeri* D'ORB., *Quinqueloculina fluviata* VENGL., *Quinqueloculina latelacunata* VENGL. and *Quinqueloculina karreri* REUSS. A characteristic feature of the limestone microbiofacies of littoral character of the substage is the rock-forming occurrence of Miliolina species. In the same facies, the species *Nodophthalmidium tibium* PARK.—JON. is very common.

At such places where the sediments of the Kozárdian substage develop gradually from the Upper Badenian sediments, *the oldest Sarmatian members contain also persistent stenohaline foraminifers* such as small-size *Bolivina* sp., *Borelis melo* FICHT.—MOLL., *Anomalina* sp., *Textularia* sp. This oldest microbiofacies is observable, in some cases, at the base of transgressive sequences, too. Sediments bearing stenohaline forams have been found in some boreholes of Kisújszállás, Csanádalberti, Ebes, Hajdúszoboszló and Józsa. The following ostracods have been determined by SZÉLES, M. in Kozárdian sediments: *Cytheridea punctillata* BRADY, *Cytheridea elongata* BRADY, *Cytheridea hungarica* ZALÁNYI, *Cythereis speyeri* BRADY, *Ciamocytheridea leptostigma* REUSS, *Ciamocytheridea leptostigma foreolata* KOLL., *Eucythere declivis* MÜLLER, *Miocyprideis janoscheki* KOLL., *Pontocythere perangusta* ZAL., *Pontocythere elongata* BRADY, *Loxoconcha subovata* MÜLLER and *Cnestocythere lamellicosta* TRIEBEL.

Bryozoans are common and characteristic of the limestone facies. The experience shows that their vertical extension practically does not reach beyond the Kozárdian substage.

In the sediments of the *Tinnyeian substage* the foraminifers are represented by a strongly reduced number of species of the genera *Miliolina, Nonion* and *Elphidium.* (The species number is about the half of that in the Kozárdian substage.) Common species are *Triloculina consobrina* D'ORB., *Triloculina inornata* D'ORB., *Quinqueloculina hauerina* D'ORB., *Quinqueloculina mayeriana* D'ORB., *Sinzowella novorossica* SINZ.—KARR., *Nonion depressulum* WALK.—JAC., *Nonion granosum* D'ORB., *Elphidium aculeatum* D'ORB., *Elphidium crispum* LINNE, *Elphidium hauerinum* D'ORB., *Elphidium obtusum* D'ORB. and *Rotalia beccarii* LINNE (Table 1.). The miliolina are common elements in the microbiofacies, however they do not occur any more in rockforming amount in the sediments of the Tinnyeian substage. In general, this younger substage is characterized by much simpler and poorer assemblages.

The significant elements of the ostracod fauna are the species *Cytheridea mülleri* BOSQUET, *Cythereis fischeri* M. SARS., *Hemicytheria* sp., *Pontocypris declivis* MÜLLER, *Loxoconcha rhomboidea* FISCHER, *Loxoconcha rhombovalis* POKORNY and *Candona trapezoidea* ZALÁNYI.

PALEOGEOGRAPHY

The extension of the Sarmatian formations in the Tiszántúl region did not exceed considerably the frames of the preceding Badenian sedimentary basin. Only in the southern part of the region are known sediments of the Kozárdian substage

TABLE 1

Species	Upper Badenian	Kozárdian substage	Tinnyean substage
Articulina sarmatica KARR.		—	
Articulina problema BOGD.		—	
Triloculina consobrina D'ORB.	—	—	—
Triloculina sarmatica GERKE		—	—
Triloculina inflata D'ORB.		—	
Triloculina bipartita D'ORB.		—	
Triloculina inornata D'ORB.	—	—	—
Triloculina scapha D'ORB.	—	—	
QuinqueloÍulina sarmatica KARR.		—	—
Quinqueloculina akneriana D'ORB.	—	—	—
Quinqueloculina hauerina D'ORB.		—	—
Quinqueloculina pauperata D'ORB.	—	—	
Quinqueloculina bronniana D'ORB.		—	
Quinqueloculina reussi BOGD.		—	
Quinqueloculina mayeriana D'ORB.	—	—	—
Y*uinqueloculina haidingeri* D'ORB.		—	
Quinqueloculina fluvita VENGL.		—	
Quinqueloculina latelacunata VENGL.		—	
Quinqueloculina karreri REUSS		—	
Massilina haidingeri D'ORB.	—	—	
Sinzowella novorossica KARR.—SINZ.		—	—
Nodophthalmidium tibium PARK.—JON.	—	—	
Nodobaculariella sp.		—	
Haplophrogmium lituus KARR.		—	
Saccamina sarmatica VENGL.		—	
Nonion depressulum WALK.—JAC.	—	—	—
Nonion granosum D'ORB.		—	—
Nonion serenus VENGL.			—

TABLE 1; Continued

Species	Upper Badenian	Kozárdian substage	Tinnyean substage
Elphidium aculeatum D'ORB.	—	—	—
Elphidium crispum LINNE	—	—	—
Elphidium fichtelianum D'ORB.	—	—	—
Elphidium hauerinum D'ORB.	—	—	—
Elphidium antoninum D'ORB.	—	—	
Elphidium josephinum D'ORB.		—	
Elphidium listeri D'ORB.		—	—
Elphidium obtusum D'ORB.	—	—	—
Elphidium rugosom D'ORB.		—	—
Elphidium reginum D'ORB.		—	
Elphidium imperatrix BRADY		—	
Elphidium macellum D'ORB.		—	—
Elphidium incertum WIEL.		—	
Elphidium striatopunctatum FICHT.—MOLL.		—	
Dendritina arbuscula D'ORB.		—	
Dendritina elagans D'ORB.	—	—	
Dendritina juleana D'ORB.		—	—
Cibicides lobatulus WALK.—JAC.	—	—	
Rotalia beccarii LINNE	—	—	—
Borelis melo FICHT.—MOLL	—		
Discorbis obtusus D'ORB.	—		
Discorbis vilardeboana D'ORB.	—		
Bolivina dilatata REUSS	—		

to overlie transgressively more ancient rocks. Relying upon presentday evidence one can state that the Badenian sedimentary basin was added several island during the Sarmatian age. The measure of overflooding was not uniform within the Sarmatian time interval, as testified to by the Tinnyeian transgressive beds of the boreholes at Furta—Zsáka. Unfortunately, the erosion period that followed the Sarmatian makes impossible the more exact reconstruction of paleogeography.

The formations of *the Kozárdian substage* have been hit upon in the most part of the Tiszántúl area. In the southern sector of the Tiszántúl, several details of the ancient shore-line could be reliably reconstructed on the base of transgressive sequences *(Fig. 3)*. The exploration of the deep Neogene depressions in the southern part of the Great Plain did not promote the knowledge of the Upper Miocene formations, but we have good reasons for assuming that those areas also belonged to the Sarmatian sedimentary basin. In the central and southern part of the Tiszántúl one can deduce a very unquiet shoreline, a series of islands, and generally shallow water (as proved by the mostly littoral sediments). Only in the depression situated between Nagyvárad (Oradea) and Szatmárnémeti (Satu Mare) filled up with chiefly detrital sediments may have existed a deeper partial basin open towards the high sea. In the Northern Tiszántúl during the time range of the Kozárdian an accumulation of rhyolitic and rhyodacitic tuffs was going on. Early Sarmatian brackish water sediment are of rather restricted extension in this area.

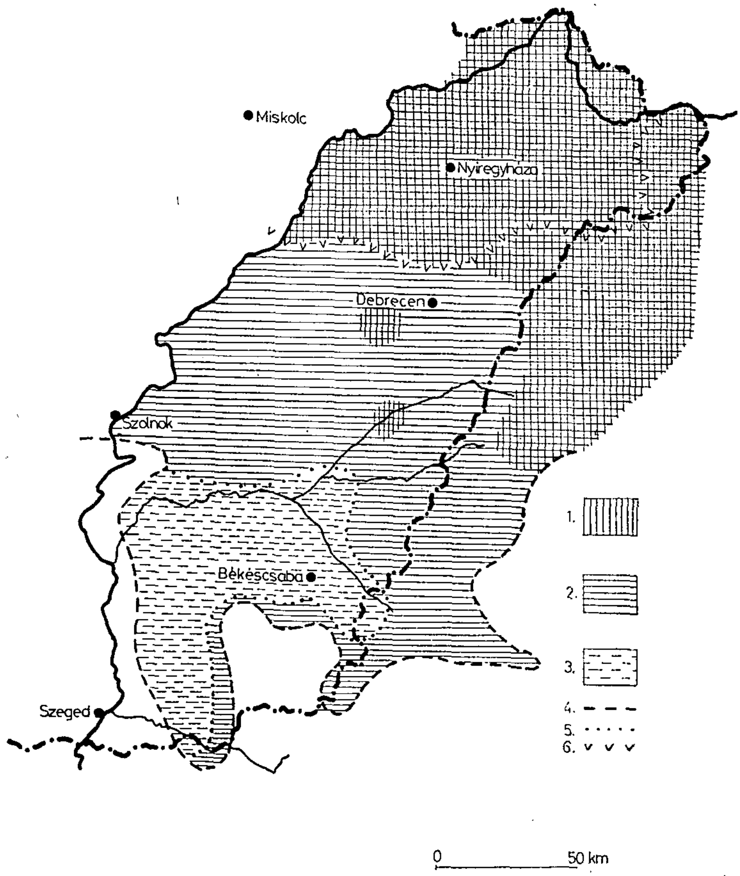

Fig. 3. Sketch of the extension of Sarmatian formations in the Tiszántúl region

Legend

1. Formations of the Tinnyeian substage
2. Formations of the Kozárdian substage
3. Hypothetic extension of hitherto not explored Sarmatian
4. Shoreline (established)
5. Extension contours of the hypothetic Sarmatian sediments
6. Contours of extension of the continental volcanogenic formations (mostly of the Kozárdian substage

The present-day distribution of the formations of *the Tinnyeian substage* provide poor information concerning the original paleogeographic setting. The actually isolated occurrences must have been came into being in a much larger sedimentary basin.

The truncated Tinnyean sequences and the biostratigraphically proved gradually transgressive nature of Lower Pannonian formation one has to count with a *denudation on the greatest part of Tiszántúl (with the exception of the deep depressions) at the Late Miocene Early Pannonian boundary.* The late Sarmatian sediments develop, at least at some places, gradually from the early Sarmatian beds (at Hajdúszoboszló), at other places they are transgressive (at Furta—Zsáka, Nyírlugos, Nyíregyháza, Tisztaberek). It is very likely that at the beginning of the Tinnyeian age further paleogeographic changes occurred in the sedimentary basin. In some areas the sedimentation was going on, others became emergent land, and at several places the transgression proceeded. The increased percentage of detrital-clastic sediments relates to the intensification of material supply. Most probably the increase in freshwater supply and the starting isolation of the partial basins combined produced the changes observable in the microfaunal assemblages. The water of the late Sarmatian sedimentary basin gradually lost salinity. Purely freshwater sediments are not known in the Tiszántúl region; eventually the clastic, faunistically sterile sediments of the Nagyvárad (Oradea) partial basin may represent the terminal portion of the stage.

The area of accumulation of continental tuffs became restricted in comparison to the Kozárdian substage, but the volcanic activity has not ceased yet. In the Tinnylean sequences of the Northern Tiszántúl the considerable amount of tuffites and tuffs proves the continuation of volcanic activity.

The Sarmatian sedimentary basin of the Tiszántúl region was delimited towards the North-West, more or less along the line to be drawn along the Tisza River from Szolnok to Tiszafüred, by a ridge consisting of acidic volcanites mostly of Badenian age. Towards the West, a continental made up mostly by crystalline rocks can be contoured. At the margin of the ridge in the Danube-Tisza interfluve numerous boreholes disclosed formations of the Kozárdian substage, supporting, by their transgressive position, the presence of the shoreline in that area.

The connexion with the Sarmatian sedimentary basin known to have existed in the Danube-Tisza interfluve can be proved by means of the boreholes drilled in the area of Szolnok and Szandaszőlős.

Connections to the northern part of Hungarian Plain can be traced at hand of the Sarmatian formations known from the boreholes of Hajdúnánás and Balmazújváros. One may assume that several connexions may have existed during some restricted intervals within the Sarmatian between the Tiszántúl region and the neighbouring areas.

In the territory of the Hungarian Plain beside the Sarmatian sedimentary basin of the Tiszántúl region *three* Late Miocene basin parts can be distinguished on the basis of hydrocarbon drilling. In the central and southern parts of the *Danube-Tisza interfluve* the facies and the stratigraphic setting are identical with those of the Tiszántúl.

In the vicinity of Gödöllő, Tura, Jászberény and Farmos there is a small-size partial basin filled up by Kozárdian and Tinnyeian brackish water sediments and subordinately by continental tuffs. This may have been directly and uninterruptedly connected with the sedimentary basin of the *Northern Hungarian Plain*, which is paralell with the present-day margin of the basin. These varying Sarmatian-formations can be correlated without any difficulty with the Sarmatian of the Northern Central Mountains.

The Sarmatian sediments of the Tiszántúl region can be correlated biostratigraphically, relying upon identities of the microfaunal assemblages, with those of the surrounding basin areas.

The tripartite Sarmatian known in the Neogene depression of *Soviet Transcarpathia* has microfaunal assemblages which permit a fairly good correlation nothwithstanding the very different lithostratigraphy [Pishvanova, L.—Tkatshenko, O. F., 1971, Gurzhiy, D. V.—Venglinskiy, I. V., 1970, Boda, J., 1974, Sviridenko, V. G., 1976]. The *Dorogobrativska Zone* corresponds in Hungary to the oldest beds containing persistent marine foraminifers. This and the *Lukivska Zone* combined fill out the time range of the Kozárdian. The *Almaska Zone*, according to its microfauna, is the equivalent of the Tinnyean substage. It may be some-what more complete than the Tinnyean in the Hungarian Plain. These two units may be considered more or less equivalent.

The Sarmatian formations of the *East-Slovakian Basin* known in the neighbouring areas to the Hungarian Plain, as based upon data published by Svagrovsky, J. [1971] are fairly well correlable, at least as concerns the older member. Accordingly, the Kozárdian substage comprises the *Olšava* and *Myšl'a* beds. The correlation of the "*tufaceous-lignitic series*" and the Tinnyean substage is much more problematic at present.

Relying upon the investigation of the Sarmatian formations disclosed by hydrocarbon exploratory drilling in the Tiszántúl region the authors think to have successfully proved also for this region the bipartite nature of the Sarmatian in Hungary as well as the presence of one part of the Bessarabian substage of Eastern Europe in the Upper Miocene of Hungary.

Table 2

<table>
<tr><th colspan="2">Vienna Basin</th><th>Hungarian Great Plain</th><th>East Slovakian Lowland</th><th>Transcarpathian Depression</th><th colspan="3">Ponto-Euxin Basin</th></tr>
<tr><td colspan="5" rowspan="3">Pannonian stage
(Pannon s. s., „Meotian", Lower Pannon)</td><td>Kherson horizon</td><td rowspan="2">Khersonian</td><td rowspan="2">Upper Sarmatian</td></tr>
<tr><td>Rostow horizon</td></tr>
<tr><td>Bessarab horizon</td><td rowspan="2">Bessarabian</td><td rowspan="2">Middle Sarmatian</td></tr>
<tr><td rowspan="3">Sarmatian</td><td>Mactra Beds
Ervilia Beds</td><td>Tinnyean substage</td><td>Serie with tuffs – lignites</td><td>Almaska horizon</td><td>Bauren horizon</td></tr>
<tr><td rowspan="2">Rissoa Beds</td><td rowspan="2">Kozardian substage</td><td>Myšl'a Beds</td><td>Lukowo horizon</td><td>Volhyn horizon</td><td rowspan="2">Volhynian</td><td rowspan="2">Lower Sarmatian</td></tr>
<tr><td>Olšava Beds</td><td>Dorogobrativska horizon</td><td>Kuyor horizon</td></tr>
<tr><td colspan="4">Upper Badenian</td><td>Bashevsk horizon</td><td colspan="3">Vesselyanka Beds</td></tr>
</table>

The attempt made on stratigraphic correlation, utilizing the data published in the papers listed in the references, is presented in Table 2. Notwithstanding the great number of borehole data, no reasonable suggestion can be made as to the time correlation of the Early Pannonian sediments of Hungary with the Late- and partly Middle Sarmatian of Southeastern-Europe.

REFERENCES

BODA, J. [1959]: A magyarországi szarmata emelet és gerinctelen faunája. (The Sartamian Stage in Hungary and its Invertebrate Fauna.) — MÁFI Évkönyv *47*, p. 569—862.

BODA, J. [1971]: A magyarországi szarmata emelet tagolása a gerinctelen fauna alapján. (The Subdivision of Sarmatian is Hungary based on the Invertebrate Fauna.) — Földt. Közl., *101*, p. 107—113.

BODA, J. [1974]: A magyarországi szarmata emelet rétegtana. (Stratigraphy of the Sarmatian in Hungary.) — Földt. Közl., *104*, p. 249—260.

GURZHIY, D. V. — VENGLINSKIY, I. V. [1971]: Facii neogena Predkarpatskogo i Zakarpatskogo progibov. — Acta Geol. Acad. Sci. Hung., *14*, p. 393—405.

ISTOCESCU, D. — IONESCU, G. [1968]: Geologia parţii de nord a Depresiunii Panonice (sectorul Oradea-Satu Mare.) — Dari de seăma ale sedintelor *55*, p. 73—87.

JÁMBOR, Á. [1971]: A magyarországi szarmata. (The Sarmatian in Hungary.) — Földt. Közl., *101*, p. 103—106.

KOJUMDGIEWA, E. [1971]: Gliederung und Korrelation der Sarmatbildungen in der Becken des Paratethys. — Földt. Közl., *101*, p. 209—216.

K. LAKY, I. [1966]: A magyarországi szarmata foraminiferák. (Sarmatian Foraminifera in Hungary.) — MÁFI Évi jel. 1964. évről, p. 475—493.

KŐRÖSSY, L. [1956]: A Tiszántúl északi részén végzett kőolajkutatás eredményei. (Results of hydrocarbon prospecting in the northern part of the Tiszántúl region.) — Földt. Közl., *86*, p. 390—402

KŐRÖSSY, L. [1971]: Mélyföldtani és fejlődéstörténeti vázlatok a magyarországi pannonból. — In: A magyarországi pannonkori képződmények kutatásai. (Sketches on Subsurface Geology and Evolution of the Pannonian in Hungary. — In: Studies on the Pannonian Formations in Hungary.) — Akadémiai kiadó, Budapest.

KŐVÁRY, J. [1965]: A magyarországi szarmata üledékek Foraminifera vizsgálata (Investigation in the Foraminifera of the Sarmatian in Hungary.) — *Manuscript*.

KŐVÁRY, J. [1973]: Szénhidrogénkutató fúrások által a Kelet- és Délkelet-Tiszántúlon feltárt neogén tengeri üledékek mikrobiofácies vizsgálata. ((Investigations into the Microbiofacies of Neogene Marine Sediments Disclosed by Hydrocarbon Exploratory Boreholes in the Eastern and Southeastern Parts of the Tiszántúl region.) — *Manuscript*.

KRETZOI, M. [1961]: A diósdi gerinces fauna és a miocén-pliocén határ kérdése. (The Vertebrate Fauna from Diósd and the Problem of the Miocene (Pliocene Boundary.) — Földt. Közl., *91*, p. 208—214.

MOTAS, J. — MARINESCU, FL. [1971]: L'evolution et subdivisions du Sarmatien dans le Bassin dacique. — Földt. Közl., *101*, p. 240—243.

PANTÓ, G. [1965]: Miozän Tuffhorizonte Ungarns. — Acta Geol. Acad. Sci. Hung., *9*, p. 225—233.

PISHVANOVA, L. — TKATCHENKO, O. F. [1971]: Paleogeograficheskie karty miocena zapadnyh oblastei USSR. — Földt. Közl., *101*, p. 265—276.

SCHMIDT, E. R. [1939]: A kincstár csonkamagyarországi szénhidrogénkutató mélyfúrásai. (Hydrocarbon drilling done by the State Treasury in Post-World-War I. in Hungary.) — Földt. Intézet Évkönyve *34*, p. 267.

SCHRÉTER, Z. [1941]: A Kárpátok által körülvett medencék szarmáciai képződményei és azok állatvilága. (The Sarmatian Formations of the Basins Enclosed by the Carpathians and their Fauna.) — Mat. Term. tud. Ért., *60*, p. 243—294.

SVAGROVSKY, J. [1971]: Die Bedeutung des Studiums der Mollusken für die Bestimmung der Biostratigraphie der sarmatischen Sedimente der Tschechoslowakei. — Földt. Közl., *101*, p. 307—311.

SZEPESHÁZY, K. [1971]: A Tiszántúl középső részének miocén képződményei a szénhidrogénkutató mélyfúrások adatai alapján. (The Miocene Formations in the Central Part of the Tiszántúl as Revealed by Hydrocarbon Drilling.) — MÁFI Évi jelentése 1968. évről, p. 297—326.

SZÉLES, M. [1958]: A magyarországi szarmata üledékek Ostracoda vizsgálata. (Investigation on the Ostracods of the Sarmatian Sediments in Hungary.) — *Manuscript*.

Széles, M. [1970]: A felsőmiocén (szarmata) képződmények rétegtani értelmezése az alföldi szénhidrogénkatutó fúrások alapján. (Stratigraphic Interpretation of the Upper Miocene (Sarmatian) Formations Based on Hydrocarbon Drilling Evidence in the Hungarian Plain.) — Földt. Közl., *100*, p. 132—143.
Sviridenko. V. G. [1976]: A kárpátaljai süllyedék és aljzatának földtani felépítése és szénhidrogénföldtana. (Geological Setting and Hydrocarbon Geology of the Transcarpathian Depression and its Basement.) — Földt. Közl., *106*, p. 464—475.
Völgyi, L. [1959]: A nagyalföldi kőolajkutatás újabb eredményei. (New Results of Oil Prospecting in the Hungarian Plain.) — Földt. Közl., *89*, p. 37—52.
Völgyi, L. [1965]: A Nagyalföld középső részének mélyföldtani vizsgálata. (Investigation to the Subsurface Geology of the Hungarian Great Palin.) — Földt. Közl., *95*, p. 140—163.

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NEWER CALCAREOUS SPONGES FROM THE WETTERSTEIN REEF LIMESTONE OF ALSÓHEGY KARSTPLATEAU (SILICA NAPPE, WESTERN CARPATHIANS, NORTH HUNGARY)

S. KOVÁCS

INTRODUCTION

Numerous Sphinctozoa (segmented calcareous sponges) and a few Inozoa (non-segmented calcareous sponges) have been worked up since the publication of the first part [BALOGH and KOVÁCS, 1976]. Unfortunately, the great part of the fauna is more or less recrystallized, allowing a generic determination only, or not even that. Despite the fact, that inozoans, mainly belonging to the form-groups of *Peronidella* and *Leiospongia,* are the most frequent reef-building organisms in the Wetterstein Reef Limestone of Alsóhegy, their closer determination is only rarely possible, because they are far less known from thin section than the sphinctozoans.

BALOGH and KOVÁCS [1976] assigned the Wetterstein Limestone of Alsóhegy to be of Ladinian—Cordevolian age. However, this facies of the Silica nappe (at least on Alsóhegy and at Silická Brezová) ranges up to the base of the Tuvalian (KOLLÁROVÁ—ANDRUSOVOVÁ and BYSTRICKÝ, 1974; KOZUR and MOCK, 1974; MIŠÍK and BORZA, 1976; KOVÁCS, 1977]. Therefore, the age of these sponges is Ladinian—Julian (or perhaps Lowermost Tuvalian).

A more exact age can be established in the case of the sponges found on the western half of the Alsóhegy, namely along the forestry road leading from Bódvaszilas to Szabó-parlag and in the environ of Vápenyica-hill, becasue there are sporadic dasycladacean-finds from the reef limestone on both locality. On the former area *Poikiloporella duplicata* (PIA) and *Physoporella heraki* BYSTRICKÝ have been found (thin sections 6/1972/A_1,A_2) together with *Stylothalamia dehmi* OTT in the same rock sample, while on the latter area *Physoporella heraki* BYSTRICKÝ and *Poikiloporella brezovica* [BYSTRICKÝ] have been found in the thin section 223/1950 B.K., together with *Cryptocoelia* cf. *zitteli* STEINMANN [BALOGH and KOVÁCS, 1976, Pl. 3, *Fig. 5*]. Consequently, the age of the sponges found here is already Carnian.

Three new Sphinctozoa species have been found here, *Vesicocaulis multisiphonatus* n. sp., *Paravesicocaulis concentricus* n. gen. n. sp. and *Verticillites trassicus* n. sp. They will be published elsewhere [KOVÁCS, 1978, in press].

DESCRIPTION

Class: Calcispongea DE BLAINVILLE, 1834
Order: Pharetronida ZITTEL, 1878
Suborder: Inozoa STEINMANN, 1882
Genus: Sestrostomella ZITTEL, 1879

?*Sestrostomella* sp.
Pl. II, *Figs. 1—3*

Material: Two longitudinal sections in thin section 35/1973/B and cross sections of three single and three branching stems in thin section 35 /1973/ F.

Description: Rather recrystallized stems of 2,5—3,1 mm diameter. The length of the longer longitudinal section is 15 mm. The filling structure is of reticular-tubular type. The central channel system consists of 4—6 tubes of about 0,35 mm diameter.

Remarks: This form is resembling to the genus *Sestrostomella* ZITTEL, 1879 by the type of the central channel system consisting of more tubes. Closer determination is impossible because of the recrystallisation.

Locality: On the southern slope of Vápenyica-hill.

Genus: *Corynella* ZITTEL, 1879

Corynella sp.
Pl. 1, Fig. 5

Material: One specimen in thin section 35 /1973/ I.

Description: Globular sponge of 16—18 mm diameter. The skeleton is reticular, with radial epirrhysae and concentrical aporrhysae.

Remarks: This form is resembling in shape and in the arrangement of the epirrhysae and the aporrhysae to the forms described by VINASSA DE REGNY: *Corynella rauffi* [1901, p. 8—9, text-figs. 1—2, Pl. 2, Figs. 1—4] and *Corynella ritae* [1907, p. 7—8, text.-fig. 1, Pl. 2, Fig. 2—5].

Locality: On the southern slope of Vápenyica-hill.

Genus: *Peronidella* HINDE, 1893

Peronidella aff. *loretzi* [ZITTEL, 1879]
Pl. I, *Fig. 3—4*

Material: Two specimens in thin sections T—204/1974 and 34/1973/C.

Description: In the thin section T—204/1974 the axial section of a 11,2 mm long, cylindrical, slightly curved stem can be seen. Its diameter is 4 mm, while that of the central channel is 1 mm.

In the other thin section a cross section is visible; its diameter is 6 mm, that of the central channel is 2 mm. Its skeleton is somewhat coarser than that of the former. Reticular filling structure, which is thickened toward both the outer and inner walls.

Remarks: This form differs from *Peronidella loretzi* [ZITTEL] only in size; this is about one-fifth of that [the average max. diameter of that is 20 mm, according to DIECI *et al.*, 1970, p. 118].

Locality: On the western part of Alsóhegy, north of Vápenyica-hill.

Peronidella cf. *subcaespitosa* (MÜNSTER, 1841)
Pl. I, *Fig. 1*

Material: One exemplar in thin section 19 /1972/ D.

Description: Slightly oblique section of a 28 mm long, curved stem. Its diameter is below 4,3, above 7,3 mm. Besides the central channel of 1,5 mm diameter there are secondary channels of 0,4—0,7 mm diameter, too; they are also longitudinal.

Remarks: This form is similar to *Peronidella subcaespitosa* [MÜNSTER, 1841] by having longitudinal secondary channels. However, sure identification is impossible, because of the poor preservation.

Locality: On the side of the forestry road from Bódvaszilas to Szabó-parlag.

Genus: *Leiospongia* d'ORBIGNY, 1849

Leiospongia sp.

Pl. I, *Fig. 6*

Material: One exemplar on the weathered rock surface of the hand-specimen 2/1972.

Description: A circular cross-section of a stem is visible on the weathered rock surface, the diameter of which is 30 mm. Coarse reticular skeleton. The sponge has no central channel.

Locality: Along the forestry road, leading from Bódvaszilas to Szabó-parlag.

Suborder: Sphinctozoa STEIMANN, 1882
Superfamily: Aporata SEILACHER, 1962
Family: Thaumastocoeliidae OTT, 1967
Genus: *Sollasia* STEIMANN, 1882

Sollasia sp.

Pl. III, *Figs. 1—3*

Material: One exemplar in thin sections T—467/A_1 and T—467/A_2.

Description: In the thin section T—467/A_1 a catenulate stem consisting of three chambers can be seen. The shape and the diameter of the chambers are different: the lower one is elongated, the middle one is subspheroidal, and the considerably larger upper one is irregular-globular. Their diameter are 5,9, 6,8 and 10,5 mm. The central channel is of cryptosiphonate type. It can be seen at the contact of the lower and the middle segments and narrows upwardly (diameter below 2,4, above 1,4 mm). The chambers are filled with vesiculae. The 0,3—0,45 mm thick wall consists of two layers, an outer, thicker spherolitic one and an inner, thinner micritic one. The wall is pierced by ostiae of 0,1—0,25 mm diameter.

In the thin section T—467/A_2 a tangential section of the spherolitic outer layer of the wall (Pl. III, *Fig. 2*) and a part of a chamber can be seen. The ostiae (diameter: 0,12—0,27 mm) of the former seem to be grouped into a sieve-field (?).

Remarks: This form corresponds to the genus *Sollasia* STEINMANN by the double wall, the outer layer of which is spherolitic, and by the fact, that the lower two chambers are connected with a single, large opening.

Locality: On the southern slope of Alsóhegy above the quarry east of Tornanádaska.

Family: Celyphiidae DE LAUBENFELS, 1955
Genus: *Follicatena* OTT, 1967

Follicatena cautica OTT, 1967

Pl. IV, *Fig. 5*

Follicatena cautica — OTT, 1967b, p. 22, Pl. 1, *Figs.* 1—7; *F. cautica* — JABLONSKÝ, 1971, p. 336, *Figs. 1—2;* *F. cautica* — JABLONSKÝ, 1974, p. 190, Pl. 17, *Fig. 1;* *F. cautica* — BALOGH and KOVÁCS, 1976, p. 298—299, Pl. 1, *Fig. 2;* Pl. 3, *Fig. 2.*

Material: One exemplar in thin section 7/1972.

Description: A single, curved stem of 4,3 max. diameter. The 0,15—0,6 mm thick wall is pierced by ostiae; their diameter is 0,06—0,12 mm. In the uppermost chamber three ostiae are grouped into a sieve-field. Chambers are filled with vesiculae.

Locality: On the side of the forestry road from Bódvaszilas to Szabó-parlag.

Follicatea cf. *cautica* OTT

Pl. IV, *Fig. 2*

Material: 4 exemplars in thin section T—496/B, E, H and T—495/A.

Description: Catenulate stems built up by subspheroidal chambers of 3,2—**5,2**—6,4 mm diameter and 3,1—**4,6**—5,6 mm height. The 0,2—0,6 mm thick wall is totally recrystallized, but the ostiae of 0,2 mm diameter still can be seen. The wall is doubled at the segment-contacts. The inner of the chambers is generally filled with two calcite generations; the first, overgrown on the wall, is fibrous, the second is mosaic, but there is micrite in some chambers instead of it. In some places ghosts of vesiculae can be seen.

Remarks: The more important features coincide with the specific marks of *Follicatena cautica* OTT (measurements, ostiae, doubled wall at the segment-contacts), but because of the total recrystallization only a determination as cf. is possible.

Locality: Vecsembükk, north of Bódvaszilas.

Follicatena n. sp.

Pl. IV, *Figs. 3—4*

Material: One exemplar in thin section T—124 /1974/ A.

Description: Two ovaloid, elongated chambers of 3,6 mm max. width and 7,5, resp. 7,0 mm height. They are filled with vesiculae. The thickness of the wall, doubled at the segment contact, is between 0,3—0,6 mm. Fairly regularly and densely settled spiculae of 0,03—0,06 mm diameter can be seen in it. It is covered outside by an epidermis of 0,12—0,24 mm thickness, which consists of an inner, rime-like, dark, micritic part and an outer, light, sparitic part. (Pl. IV, *Fig. 4*) A sieve-field can be seen on both chambers: the lower one consists of three, the upper one from six ostiae. The diameter of the ostiae is 0,12 mm or so.

Remarks: This form differs from *Follicatena cautica* OTT by the width/height rate, which is 0,5, while at that species mostly 1,0 (even such rate cannot be seen on the width/height diagramm of that — OTT, 1967, p. 21). Furthermore, the rime-like epidermis has not been mentioned by OTT and cannot be seen on his figures. However, establishing a new species is unfounded, because of the only two chambers.

Locality: NNW of the Pasnyak-spring, on the edge of the plateau.

Genus: *Vesicocaulis* OTT, 1967

Vesicocaulis carinthiacus OTT, 1968

Pl. V, *Fig. 2*

Vesicocaulis carinthiacus — OTT, in KRAUS and OTT, 1968, p. 276—277, Pl. 20, *Figs. 2-4; V. carinthiacus* — WOLFF, 1973, Abb. 4, Fig. 4; *V. carinthiacus* — JABLONSKÝ, 1974, p. 191—192, Pl. 67, *Fig. 2.*

Material: Two stems in thin section T—500/A.

Description: The diameter of the stems, built up by flat, pressed chambers, is 2,1—2,3 mm, resp. 2,2 mm. The width/height index of the segments is 2,33 (measured on 16 chambers). The central channel system, the width of which is 1,05, resp. 1,2 mm, is composed of more tubes of 0,4—0,6 mm diameter. The wall (thickness: 0,06—0,09 mm) is pierced by ostiae of 0,03—0,06 mm. Vesiculae can only be found in one stem. The moderately developed reticular mantle of the central channel system can only be seen in some places.

Remarks: Though the width/heigth index of our exemplars is somewhat greater than those reported by OTT in the original description [1,88, in KRAUS and OTT, 1968, p. 277], all characteristic features correspond to *Vesicocaulis carinthiacus* OTT.

Locality: Vecsembükk, north of Bódvaszilas.

Vesicocaulis depressus OTT, 1967
Pl. V, *Figs. 1, 4*

Vesicocaulis depressus — OTT, 1976, p. 26, Pl. 3, *Figs. 1—4; V. depressus* — DIECI, ANTONACCI and ZARDINI, 1970, p. 138, Pl. 27, Figs. *14—18; V. depressus* — JABLONSKÝ, 1971, p, 337. text-*fig. 3;* (?) *V.* cf. *depressus* — MIŠIK, 1972, Pl. 20, *Fig. 2; V. depressus* — BALOGH and KOVÁCS, 1976, p. 299, Pl. 2, *Figs. 1, 3.*

Material: Several exemplars in thin sections 35/1973/A, B, C.

Description: The curved, catenulate stems of 2,5—4,2 mm diameter are built up by flat, shield-like overlapping segments. The height of the segments is 0,55—0,9 mm, their width/height index is between 3,5—5. The central channel system takes about the half diameter of the sponge and consists of 3—6 tubes of 0,3—0,45 mm diameter. The thin (0,06—0,12 mm) wall is pierced by ostiae, the diameter of which is 0,03—0,09 mm. Vesiculae can rarely be found either in the chambers and or in the central channel.

Locality: On the southwestern slope of Vápenyica-hill.

Vesicocaulis cf. *reticuliformis* JABLONSKÝ, 1972
Pl. V, *Fig. 3*

Vesicocaulis carinthiacus — JABLONSKÝ, 1971, p. 338—339, text-*fig. 4; Vesicocaulis reticuliformis* — JABLONSKÝ, 1972, p. 361—364, text-*figs. 1—5.*

Material: One exemplar in thin section T—124/B.

Description: A catenulate stem built up by four globular chambers. Its max. diameter is 4,9 mm, the height of the chambers is 2,3—4,6 mm. The chambers are filled with reticular filling structure, but there are vesiculae in them, too. The diameter of the central channel system is 2 mm or so. Three tubes of 0,4—0,5 mm diameter can be seen from this system in the thin section. Wall-thickness is 0,15—0,3 mm.

Remarks: The main features of this form corresponds to *Vesicocaulis reticuliformis* JABLSHÝ, 1972,ONKStbu e tegments are almost as high as wide, while at that species they are 2—3 times wide as high [JABLONSKÝ, 1972, p. 363].

Locality: On the edge of the plateau, NNW of Pasnyak-spring.

Superfamily: Porata SEILACHER, 1962
Family: Guadalupiidae GIRTY, 1908
Genus: *Guadalupia* GIRTY, 1908

?*Guadalupia* sp.
Pl. VI, *Fig. 4*

Material: One exemplar in thin section 2 /1972/ B.

Description: A half cross section of a stem of 7 mm diameter can be seen in the thin section. It is built up by tube-like, vertical chambers, the shorter diameter of which is 0,6—1,05 mm. They are arranged in one layer around the central channel of 2,2 mm diameter. The thickness of the wall is 0,09—0,15 mm. Closely packed pores of 0,05 mm diameter pierce the outer and the inner wall and connect the vertical chambers. Neither filling structure, nor vesiculae can be seen.

Locality: Along the forestry-road leading to Szabó-parlag, northwest of Bódvaszilas.

Family: Cystothalamiidae GIRTHY, 1908
Genus: Cystothalamia GIRTY, 1908

Cystothalamia n. sp.
Pl. IV, *Fig. 1*; Pl. VI, *Fig. 5*

Material: One exemplar in thin section T—313.

Description: Oblique section of about two-third part of a glomerat stem, consisting of flat chambers. Their height is between 0,3—0,7 mm; mostly 0,6 mm; width/height ratio is 3:1—4:1 in most cases. The half-width of the stem is 6,3 mm. The central channel can be seen in full width and does not have a definite wall. Its diameter is 2,9 mm. The 0,06—0,12 mm thick wall is pierced by pores, the diameter of which is 0,1—0,2 mm in the outer wall and 0,06—0,12 mm in the chamber-walls. 3—5 of them open from each chambers. The chamber-walls consist of two layers (Pl. IV, *Fig. 1*), but there is no sharp boundary between them and the lower becomes more and more looser. Vesiculae cannot be seen.

Remarks: This form differs from *Cystothalamia bavarica* OTT by the lack of the thick wall of the central channel, the missing vesiculae and the far more flatter chambers.

Locality: On the southern edge of the plateau of Alsóhegy, east of Tornanádaska, near the eastern end of the reef facies.

?*Cystothalamia* sp.
Pl. II, *Fig. 6*

Material: Two exemplars in thin sections 35 /1973/ M and T—505.

Description: In the thin section 35 /1973/ M a small glomerat stem can be seen, having a mantle around the central channel consisting of only one layer of chambers, which is hardly developed on the left side. The length of the section is 10 mm, its maximum half-width is 2 mm on the right side. The diameter of the central channel is 1 mm. The thickness of the wall of the chambers is 0,06—0,09 mm, that of the wall of the central channel is 0,09—0,12 mm. The wall is pierced by pores of 0,06—0,09 mm diameter. Vesiculae can be seen in two chambers on the upper part.

In thin section T—505 a cross section of a stem of 6 mm width can be seen. The diameter of the central channel, having a thicker wall, is 1 mm.

Remarks: The shape of the chambers and the thicker wall of the central channel resemble to *Cystothalamia bavarica* OTT [OTT, 1967b, p. 36—38, Pl. 1, *Fig. 8*, Pl. 7,

Fig. 5; JABLONSKÝ, 1971, p. 339—341, *Figs. 5—6*], but the diameters are considerabily smaller. The specimen in thin section 35 /1973/ M can be interpreted as a juvenile form. However, a closer determination is impossible because of the imperfect development and preservation.

Locality: On the southwestern slope of the Vápenyica-hill and Vecsembükk.

Family: Sebargasiidae STEINMANN, 1882
Genus: *Colospongia* LAUBE, 1865

Colospongia n. sp.
Pl. II, *Fig. 7*; Pl. III, *Figs. 1, 4*

Material: Four exemplars in thin sections T—467/A_1 and T—467/A_2, which are made from the same hand specimen.

Description: Three of the exemplars consists of upwardly growing chambers. The diameter of the chambers varies from 1,1—1,5 mm of the smallest ones up to 4,1—6,3 mm of the largest ones. The first exemplar (Pl. III, *Fig. 1*) is grown together with a *Sollasia* sp. The size of its chambers regularly grows only up to the third one, the upper ones are irregularly and chaotically arranged. The second exemplar consists of four continouosly growing chambers (Pl. III, *Fig. 4*, at right). The third exemplar (Pl. III, *Fig. 4*, at left) branches above the second chamber. An oncoid is agglutinated in the wall of the left branch. The fourth exemplar (Pl. II, *Fig. 7*) differs from the formers, because the diameter of its chambers remains almost the same upwardly (3,2 mm in the lower and 3,9 mm in the upper one), but completely agrees with them in the character of the wall and the pores.

The thickness of the wall is 0,10—0,45 mm. The diameter of the pores is 0,10—0,15 mm and they are narrowing outwardly. They mostly exist as roof-pores, and can only rarely be found in the outer walls.

Remarks: These forms differs from *Colospongia catenulata* OTT by the outwardly narrowing pores and their smaller number; from *C. semsey* [VINASSA] by their relatively thinner walls and wider pores, as well as smaller sizes; from *C. andrusovi* JABLONSK also by their outwardly narrowing pores and by the fact, that the pores are concentrated on the segment-roofs. The greatest similarity exists with *C. dubia* [MÜNSTER], but they cannot be identified as such because of the lot of irregularities in their shape.

Locality: On the southern slope of Alsóhegy, above the quarry east of Tornanádaska.

Colospongia sp.
Pl. V, *Fig. 5*

Material: One exemplar in thin section T—50.

Description: A slightly oblique section of a branching stem, consisting of spheroidal, hollow chambers, which seem to increase upwardly. The diameter of the larger ones is 5,6—6,3 mm. No vesiculae are in them. The 0,55—0,7 mm thick wall is pierced by densely spaced pores of 0,09—0,12 mm diameter. The pore-density is 12—15/mm^2.

Remarks: This form resembles rathermost to *Colospongia dubia* [MÜNSTER], concerning its upwardly increasing chambers; however, a closer determination is impossible, because of the oblique section. It differs from the above described

Colospongia n. sp. by the more regular form of the chambers and by the fact that the pore-density is the same in the roof and in the side-wall of the chambers.

Locality: At the southern foot of Alsóhegy, about 1 km west of Tornanádaska.

Genus: *Amblysiphonella* STEINMANN, 1882

Amblysiphonella cf. *zitteli* (VINASSA DE REGNY, 1908)

Pl. II, *Fig. 5*

Material: One exemplar in thin section T—484/B.

Description: A 30 mm long, slightly funnel-shaped stem, consisting of 6 ring-chambers. Its diameter is below 13 mm, above 17 mm. The height of the chambers is 3,1—4,4 mm. Only the lower two chambers are relatively intact, the rest, including the central channel, have been injuried during imbedding and recrystallized, so the structure of the sponge is rather disturbed here. The central channel is of primary retrosiphonate type, its diameter is below 1,7, above 2,4 mm. The wall is recrystallized as a whole, so the pores have only rarely been preserved. Wall-thickness changes between 0,4—1,0 mm, the diameter of the visible pores is 0,1—0,15 mm.

Remarks: This exemplar is rathermost resembling to the figures of *Amblysiphonella (Oligocoelia) zitteli* [VINASSA DE REGNY, 1901, p. 16—17, Pl. 1, *Fig. 1—3*], but a sure identification cannot be carried out, because of the poor preservation.

Locality: On the southern edge of the plateau of Alsóhegy, above the Rongyoskút spring, east of Tornanádaska.

Amblysiphonella sp.

Pl. II, *Fig. 4*

Material: One branching exemplar in thin section T—6.

Description: Probably a branching stem; the upper branch contains four, flat segments, the lower, strongly recrystallized one only two of them. The diameter of the upper stem is below 4, above 8 mm, the height of its segments is 1,4—1,7 mm. The recrystallized wall is 0,35—0,5 mm thick and roof pores are preserved in it only in some places.

Locality: The eastern end of the quarry east of Tornanádaska.

Family: Verticillitidae STEINMANN, 1882

Genus: *Verticillites* DEFRANCE, 1869

Verticillites sp.

Pl. VI, *Figs. 1—3*

Material: Five exemplars in thin sections 2 /1972/ A (two exemplars), 2 /1972/ D, T—313/A and T—418/D.

Description: In the latter two thin sections fragments of upwardly widening cylindrical stems, while in the former two ones rather nodular forms can be seen. Their max. diameters are between 13—18 mm. They are built by flat, shield-like overlapping segments filled with loose reticular filling structure, the height of which is 0,55—0,85 mm, mostly 0,7 mm. In the filling structure tubes of 0,35—0,5 mm diameter can be seen, which may be interpreted as prosochaetes and apochaetes (Pl. VI, *Fig. 2*).

Remarks: A closer determination is impossible, because the thin sections avoided the central channel. It seems, that the rather nodular forms in the thin sections 2 /1972/ A and 2 /1972/ D may not belong to the cylindrical *Verticillites triassicus* Kovács.

Locality: Along the forestry road leading from Bódvaszilas to Szabó-parlag and on the southern edge of the plateau east of Tornanádaska.

Family: Cryptocoeliidae Steinmann, 1882

Genus: *Cryptocoelia* Steinmann, 1882

Cryptocoelia zitteli Steinmann, 1882

Pl. VII, *Figs. 4—6*

Cryptocoelia zitteli — Steinmann, 1882, p. 176—177, Pl. 7, *Figs. 1—2; C. zitteli* — Seilacher 1962, p. 751; *C. zitteli*—Ott, 1976b, p. 42—44, Pl. 9, *Figs. 5—7; C. zitteli*—Dieci, Antonacci and Zardini, 1970, p. 149, Pl. 30, *Figs. 8a—10;* Pl. 33, *Fig. 2; C. zitteli* — Jablonský, 1971, p. 342—343, *Figs. 8—9; C. zitteli* — Jablonský, 1973, p. 185—187, Pl. 1, *Figs. 1—2*, Pl. 2, *Figs. 1—2; C. zitteli* — Jablonský, 1974, p. 198, Pl. 68, *Fig. 3;* (?) *C.* cf. *zitteli* — Balogh and Kovács, 1976, p. 302, Pl. 1, *Figs. 3—4*, Pl. 3, *Fig. 5.*

Material: Several exemplars in hand specimen T—66/1974, from which the thin sections T—66/A,B,C,D,E have been made.

Description: Single or branching, often curved, catenulate stems, consisting of flat, overlapping segments. The diameter of the stems is 3,6—**5,4**—6,5 mm, the height of the chambers is between 1,1—2,1 mm. There is a trabecular filling structure in the chambers. The diameter of the pillars is 0,09—0,15 mm, but they are thickened at their contact with the segment-roofs. The density of the pillars is 5—7/mm^2. Their lamellar structure cannot be seen due to recrystallization. The 0,2—0,3 mm thick walls are pierced by pores of 0,09—0,18 mm diameter. Vesiculae are abundant.

Remarks: These forms stand nearest to those pictured by Steinmann [1882, Pl. 7, *Fig. 2*] and Jablonsk [1974, Pl. 68, *Fig. 3*]. The thickness of the pillars is smaller and the height of the segments is somewhat greater than those of the forms pictured by Ott [1967b, Pl. 9, *Figs. 5—7*] and Jablonsk [1973, Pl. 1, *Figs. 1—2*; Pl. 2, *Figs. 1—2*], but the thickness of the filling structure has no specific value, according to Ott [1967b, p. 41].

Locality: On the southern edge of the plateau of Alsóhegy, NNW of Tornanádaska, in the near of Hangyás-dolina.

Genus: *Stylothalamia* Ott, 1967

Stylothalamia n. sp. A

Pl. II, *Fig. 8*

Material: Several exemplars in thin sections T—193/C and T—482/F.

Descriptin: In the thin section T—193/C branching stems can be seen, which are likely to represent three exemplars, while there is a 40 mm long single, curved, strongly recrystallized stem in thin section T—482/F. Their diameter is about 5,5 mm and they are built of flat segments of 0,55—0,9 mm height. Central channel retrosiphonate, its diameter is 0,8—1,8 mm. The chambers are filled with trabecular filling structure, consisting of pillars of 0,10—0,15 mm thickness, which are thickened at their ends. The outer wall is thick (0,45—0,75 mm) and no pores are visible in it, due to recrystallization. The segment-roofs are thinner (0,24—0,36 mm) and pierced by pores of 0,1—0,3 mm diameter. Vesiculae cannot be seen.

Remarks: These forms differ from *Stylothalamia dehmi* OTT, 1967 by their considerably coarser skeleton and slender shape, but may not be described as new species, owing to the strong recrystallization.

Locality: On the western slope of Vápenyica-hill and on the plateau northeast of Tornanádaska, on the north-eastern side of Vizes-dolina.

Stylothalamia n. sp. B
Pl. VII, *Fig. 1*

Material: Two exemplars in thin sections T—457 and G—23/1974.

Description: Single, strait stems of 24, resp. 20 mm height and 5—6,5 mm diameter, consisting of low, overlapping segments, the height of which is 1,4—1,8 mm. The chambers are filled with fairly regular trabecular filling structure; both the pillars and the pores seem to be arranged in one row and seem to continue through more chambers. So, this structure is resembling to that of certain groups of hydrozoans, that is the segment-roofs may be interpreted as rim-like thickening of the pillars at regular intervals, leaving hollows between these thickenings, which are the pores. These pores are quite different from those of *S. dehmi*, the arrangement of which is independent of the thickened ends of the pillars. The thickness of these segment-roofs is 0,2—0,35 mm, the diameter of the trabeculae on their middle part is 0,2—0,3 mm, that of the pores is 0,15—0,30 mm.

Remarks: This form differs from *Stylothalamia* n. sp. A by its thinner skeleton and higher segments, from *S. dehmi* by the above mentioned regularity of the trabeculae and the pores.

Locality: On the southern slope of Alsóhegy, east of the Tapolca-springs.

Stylothalamia n. sp. C
Pl. VII, *Fig. 2*

Material: One exemplar in thin section 22/1972.

Description: A slightly oblique section of a max. 7,3 mm wide, 17,5 mm high stem, consisting of 11 flat, overlapping segments. In the 0,9—1,4 mm high chambers rare pillars of 0,1—0,3 mm diameter constitute the trabecular filling structure. The pillars are somewhat thickened at their ends. The thickness of the segment-roofs is 0,3—0,5 mm and remains uniform within one segment. They are pierced by pores of 0,08—0,12 mm diameter. These pores are tube-like and their diameter remains the same all over their length.

Remarks: This form stands nearest to the specimens of *S. dehmi* found on Alsóhegy, but differs from them by its considerably thicker walls and more slender shape.

Locality: On the side of the forestry road from Bódvaszilas to Szabó-parlag.

Stylothalamia n. sp. D
Pl. VII, *Fig. 3*

Material: One exemplar in thin section T—24.

Description: A slightly oblique section of a 16 mm long, 6 mm wide stem, consisting of 16, flat, overlapping segments of about 1 mm height. The thickness of the wall is 0,3—0,5 mm and differs from that of *Stylothalamia* n. sp. C since the segment-roofs are not uniformly thick, become thinner toward the pores. Rare pillars of 0,1—0,5 mm thickness, thickened at their ends, constitute the trabecular filling structure. The diameter of the pores, which funnel-like widen out upwardly, is 0,1—0,2 mm. Vesiculae are not present. The walls are completely recrystallized, and so are the filling of the chambers on some places, too.

Remarks: This form resembles to *Stylothalamia* n. sp. B in the unevenly thick segment-roofs, but differs from it by the smaller chamber-height and the coarser skeleton.

Locality: On the edge of the plateau, NNW of Pasnyak-spring.

REFERENCES

BALOGH K. and KOVÁCS S. [1976]: Spinctozoa from the reef facies of the Wetterstein limestone of Alsóhegy-mount (South Gemericum, West Carpatians, Northern Hungary). — Acta Miner. Petr., Szeged, *22*, 2, p. 297—310., Szeged.

BYSTRICKÝ, J. [1964]: Slovenský kras. Stratigraphie und Dasycladaceen des Gebirges Slovenský kras. Ústr. úst. geol., 204 p., Bratislava.

DIECI, G., ANTONACCI, A. and ZARDINI, R. [1970]: Le spugne cassiane (Trias medio-superiore) della regione dolomitica attorno a Cortina d'Ampezzo. — Boll. Soc. Paleont. Italiana, *7*, 2, p. 94—155., Modena.

FLÜGEL, H. W. [1967]: Spinctozoa aus den Klobenwand-Kalken (Trias, Mürztaler Kalkalpen) — Österr. Akad. Wiss., math.-naturw. Kl., Abt. I. *176*, 5—7, p. 61—63., Wien.

FLÜGEL, H. W. [1972]: Catalogus Fossilium Austriae. — 3a—3b: Porifera — Archaeocyatha. 31 p., Wien.

GIRTY, G. H. [1908]: The Guadalupian Fauna. — U. S. geol. Surv., Prof. Pap., *58*, 651 p., Washington.

HERAK, M. [1944]: Zur Kenntnis triadischer Kalkschwämme (Sycones), — N. Jb. Miner. etc., Abh., (B) *88*, p. 107—135., Stuttgart.

HILLEBRANDT, A. [1971]: *Stylothalamia* (Sphinctozoa, Porifera) aus dem Lias von Peru. — Mitt. Bayer. Staatssamml. Paläont. hist. Geol. *11*, p. 69—75., München.

JÁBLONSKÝ, E. [1971]: Segmentierte Kalkschwämme — Sphinctozoa der Westkarpaten (von der Lokalität Liptovská Osada). — Geol. Zborn. — Geologica Carpath., *22*, 2, p. 333—346., Bratislava.

JABLONSKÝ, E. [1972]: *Vesicocaulis reticuliformis* n. sp. (Sphinctozoa) aus der Trias der Westkarpaten. — Geol. Zborn. — Geologica Carpath., *23*, 2, p. 361—364., Bratislava.

JABLONSKÝ, E. [1973a]: Triassische Sphinctozoen aus den Westkarpaten.—Geol. Zborn.—Geologica Carpath., *24*, 1, p. 107—111., Bratislava.

JABLONSKÝ, E. [1973b]: Neue Erkenntnisse über die Morphologie der Art *Cryptozoelia ziiteli* STEINMANN, 1882 (Sphinctozoa). — Časopis pro mineralogii, *18*, 2, p. 185—187., Bratislava.

JABLONSKÝ E. [1974]: Segmentierte Kalkschwämme (Sphinctozoa) aus Wettersteinkalken einiger Gebirge der Westkarpaten. — Acta Geol. Geogr. Univ. Comenianae, Geol. *26*, p. 189—202., Bratislava.

JABLONSKÝ, E. [1975]: *Colospongia andrusovi* n. sp., eine neue Art von segmentierten Kalkschwämmen (Sphinctozoa) aus der Trias der Westkarpaten. — Geol. Zborn. — Geologica Carpath, *26*, 2, p. 267—273., Bratislava.

KLIPSTEIN, A. von [1843]: Beiträge zur geologischen Kenntniss der östlichen Alpen.—310 p., Giessen.

KOLLÁROVÁ—ANDRUSOVOVÁ, V. and BYSTRICKÝ, J. [1974]: Übersicht über den gegenwärtigen Stand der Biostratigraphie der Trias der Westkarpaten. In: Die Stratigraphie der alpin-mediterranen Trias. — Schriftenreihe Erdwiss. Komm. Österr. Akad. Wiss., Bd. 2, p. 125—136., Wien.

KOVÁCS, S. [1977]: A dél-gömöri Alsóhegy magyarországi részének földtana. (Geology of the Hungarian part of the South Gemerian Alsóhegy). Unpubl. diss., 182 p., Szeged.

KOVÁCS S. [1978]: New Sphinctozoa from the North Hungarian Triassic. — N. Jb. Geol.—Paläont. Mh. (in press).

KOZUR, H. and MOCK, R. [1974]: Die Obergrenze der karnischen Dasycladaceen-Kalke in der Lokalität Silická Brezová (Slovakischer Karst). — Vestnik Ústredniho ústava geol. *49*., p. 223—225., Bratislava.

KRAUS, O. and OTT, E. [1968]: Eine ladinische Riff-Fauna im Dobratsch-Gipfelkalk (Kärnten, Österreich) und Bemerkungen zum Faziesvergleich von Nordalpen und Drauzug. — Mitt. Bayer. Staatssamml. Paläont. Hist. Geol. *8*, p. 263—290., München.

LAUBENFELS, M. W. DE [1955]: Porifera. — Treatise invertebr. Paleont., E. p. 21—122., Lawrence, Kansas.

MELLO, J. [1976]: Facial and Stratigraphic Division ot the Wetterstein Limestones in the Czechoslovak part of Dolný vrch Karst plateau. — Geol. Práce, Správy *65*, p. 37—52., Bratislava.
MIŠÍK, M. [1972]: Lithologische und fazielle Analyse der mittleren Trias der Kerngebirge der Westkarpaten. — Acta Geol. Geogr. Univ. Comenianae, Geol. *22*, p. 5—154., Bratislava.
MIŠÍK, M. and BORZA, K. [1976]: Obere Trias bei Silická Brezová (Westkarpaten). — Acta Geol. Geogr. Univ. Comenianae, Geol. *30*, p. 5—49., Bratislava.
MÜNSTER, G. Graf zu [1841]: Beiträge zur Geognosie und Petrefacten-Kunde des südöstlichen Tirols, vorzüglich der Schichten von St. Cassian. — 152 p., Bayreuth.
OTT. E. [1976a]: Die Beziehungen zwischen *Colospongia* LAUBE, *Takreamina* FONTAINE, *Cirtycoeli* KING und *Dictycoelia* n. g. (segmentierte Kalkschwämme). — N. Jb. Geol. Paläont., Mh. p. 44—58., Stuttgart.
OTT, E. [1976b]: Segmentierte Kalkschwämme (Sphinctozoa) aus der alpinen Mitteltrias und ihre Bedeutung als Riffbildner im Wettersteinkalk. — Abh. Bayer. Akad. Wiss., math.-naturw. Kl, N. F., *131*, 96 p., München.
OTT, E. [1972]: Mitteltriadische Riffe der Nördlichen Kalkalpen und altersgleiche Bildungen auf Karaburun und Chios (Agäis). — Mitt. Ges. Geol. Bergbaustud. (Innsbruck), *21*, p. 271—276., Innsbruck.
PARONA, C. F. [1933]: Le spugne della fauna permiana di Palazzo Adriano (Bacino del Sosio) in Sicilia. — Mem. Soc. Geol. Ital., *1*, 58 p., Rome.
RAUFF, H. [1938]: Über einige Kalkschwämme aus der Trias der perianischen Kordillere, nebst einem Anhang über *Stellispongia* und ihre Arten. — Paläont, Z., *20*, p. 177—214., Berlin.
SCHOLZ, G. [1972]: An Anisian Wetterstein Limestone Reef in North Hungary. — Acta Miner. Petr. Szeged, *20*, 2, p. 337—362., Szeged.
SEILACHER, A. [1962]: Die Sphinctozoa, eine Gruppe fossiler Kalkschwämme. — Akad. Wiss. Lit., Abh. math. — naturw. Kl., (10), p. 720—790., Mainz.
STEINMANN, G. [1882]: Pharetronen-Studien. — N. Jb. Miner. etc., II, p. 139—191., Stuttgart.
VINASSA DE REGNY, P. [1901]: Trias Spongien aus dem Bakony. — Result. wiss. Erforsch. Balatonsees. *1*, Paläont. Anhang, 22 p., Budapest.
VINASSA DE REGNY, P. [1908]: Neue Schwämme, Tabulaten und Hydrozoen aus dem Bakony. Result. wiss. Erforsch. Balatonsees, *1*, (1), p. 1—17., Budapest.
VINASSA DE REGNY, P. [1915]: Triadische Algen, Spongien, Anthozoen und Bryozoen aus Timor. — Palaeont. Timor, *4*, (8), p. 73—118., Stuttgart.
WAAGEN, W. and WENTZEL, J. [1888]: Salt-Range Fossils. I. Productus-Limestone Fossils, 7. Coelenterata-Amorphozoa-Protozoa. — Mem geol. Surv. India; Palaeont. Indica, p. 925—988., Calcutta.
WILCKENS, O. [1937]: Korallen und Kalkschwämme aus dem obertriadischen Pharetronenkalk von Seran (Molukken). — N. Jb. Miner. etc., Beil.-Bd. *77*, p. 171—211., Stuttgart.
WOLFF, H. [1973]: Fazies-Gliederung und Paläogeographie des Ladins in den bayerischen Kalkalpen zwischen Wendelstein und Kampenwand. — N. Jb. Geol. Paläont., Abh. *143*, 2, p. 246—274., Stuttgart.
WÖHRMANN, S. [1889]: Die Fauna der sogenannten Cardita- und Raibler-Schichten in den nordtiroler und bayrischen Alpen. — Jb. geol. Reischsanst., *39*, p. 181—258., Wien.
ZANKL, H. [1969]: Die Göll — Aufban und Lebensbild eines Dachsteinkalk-Riffes in der Obertrias der nördlichen Kalkalpen. — Abh. Senckenberg. Naturf. Ges., *519*, 123 p., Frankfurt a. M.
ZITTEL, K. A. [1878]: Studien über fossile Spongien, III. — Abh. bayer. Akad. Wiss., math.-naturw. Kl., *13*, p. 91—138., München.

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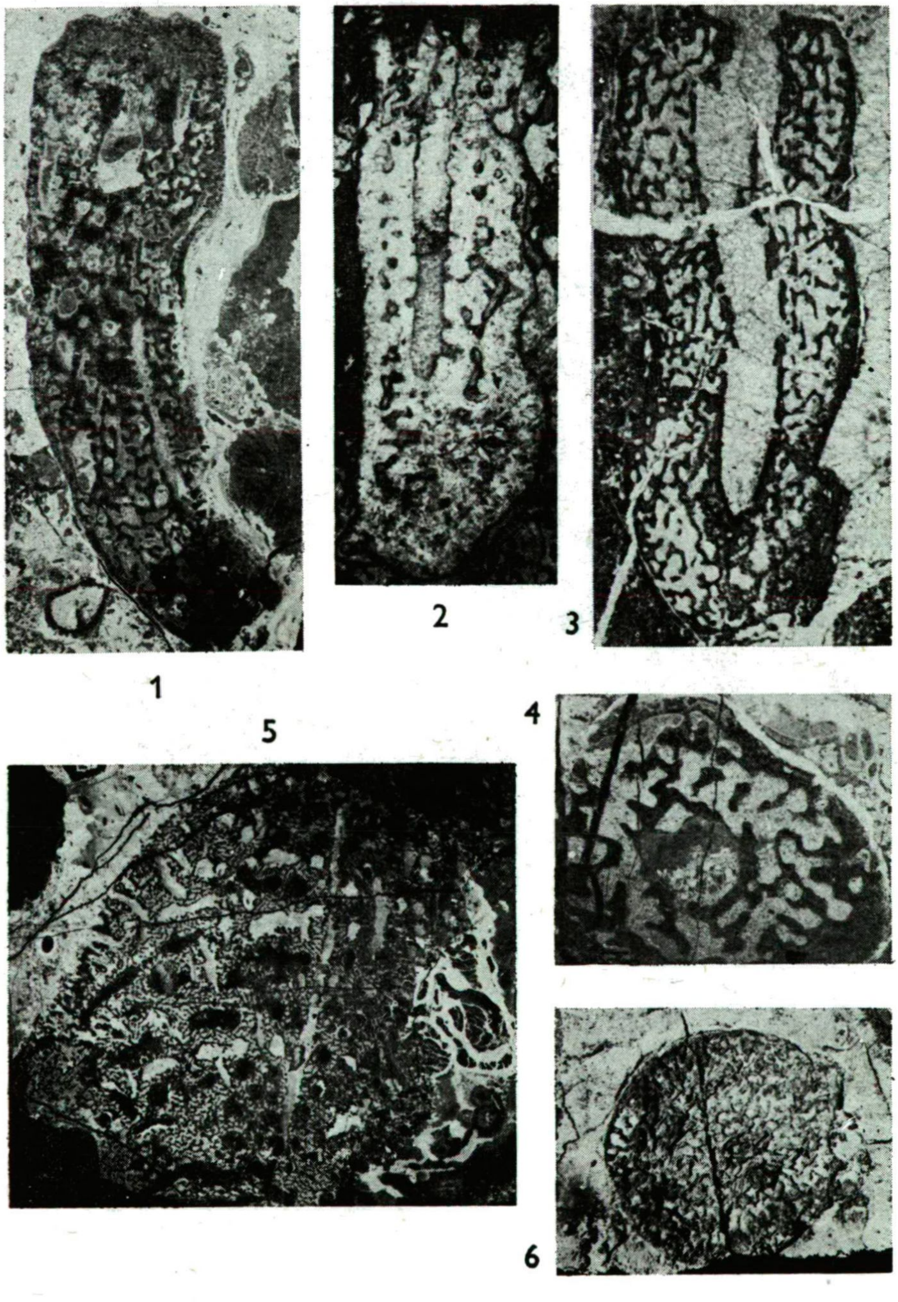
PLATE 1.



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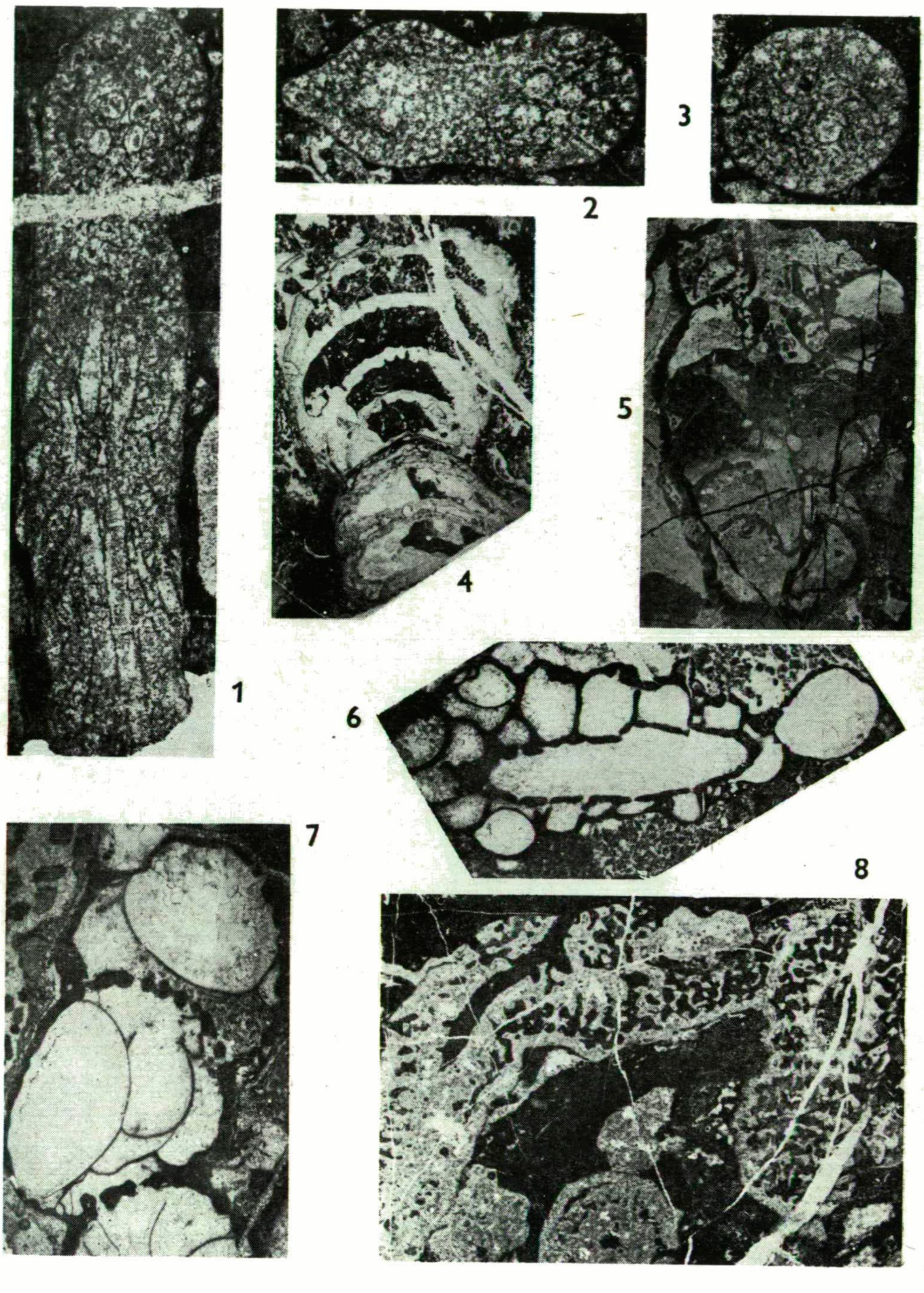

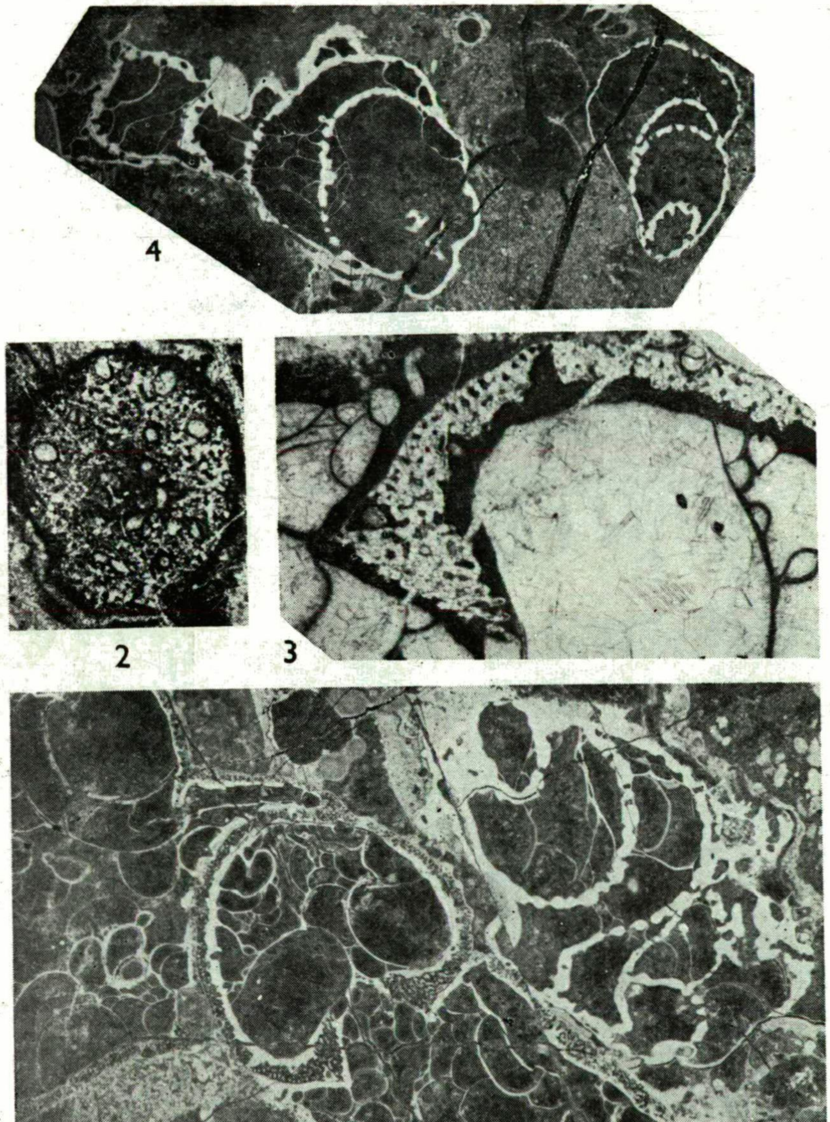
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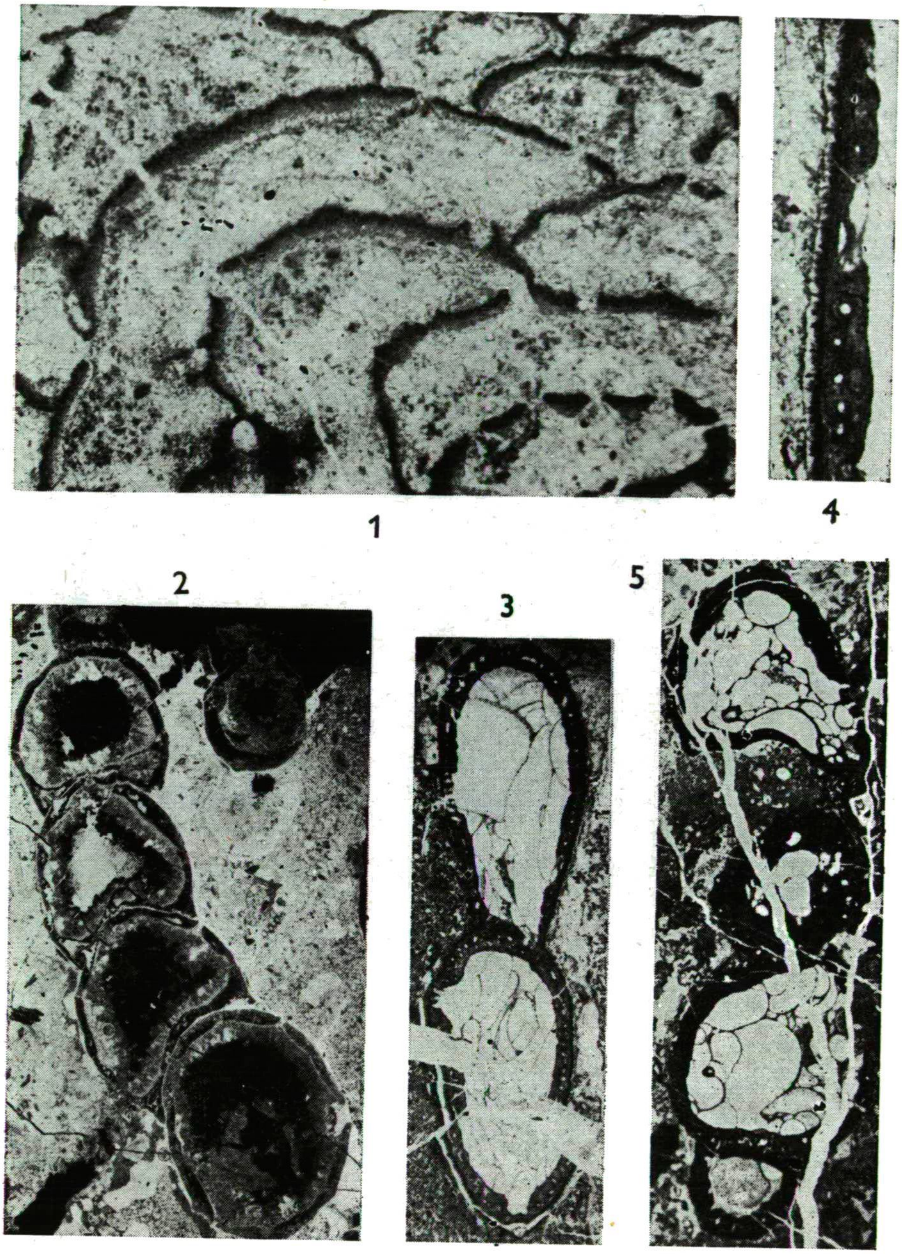

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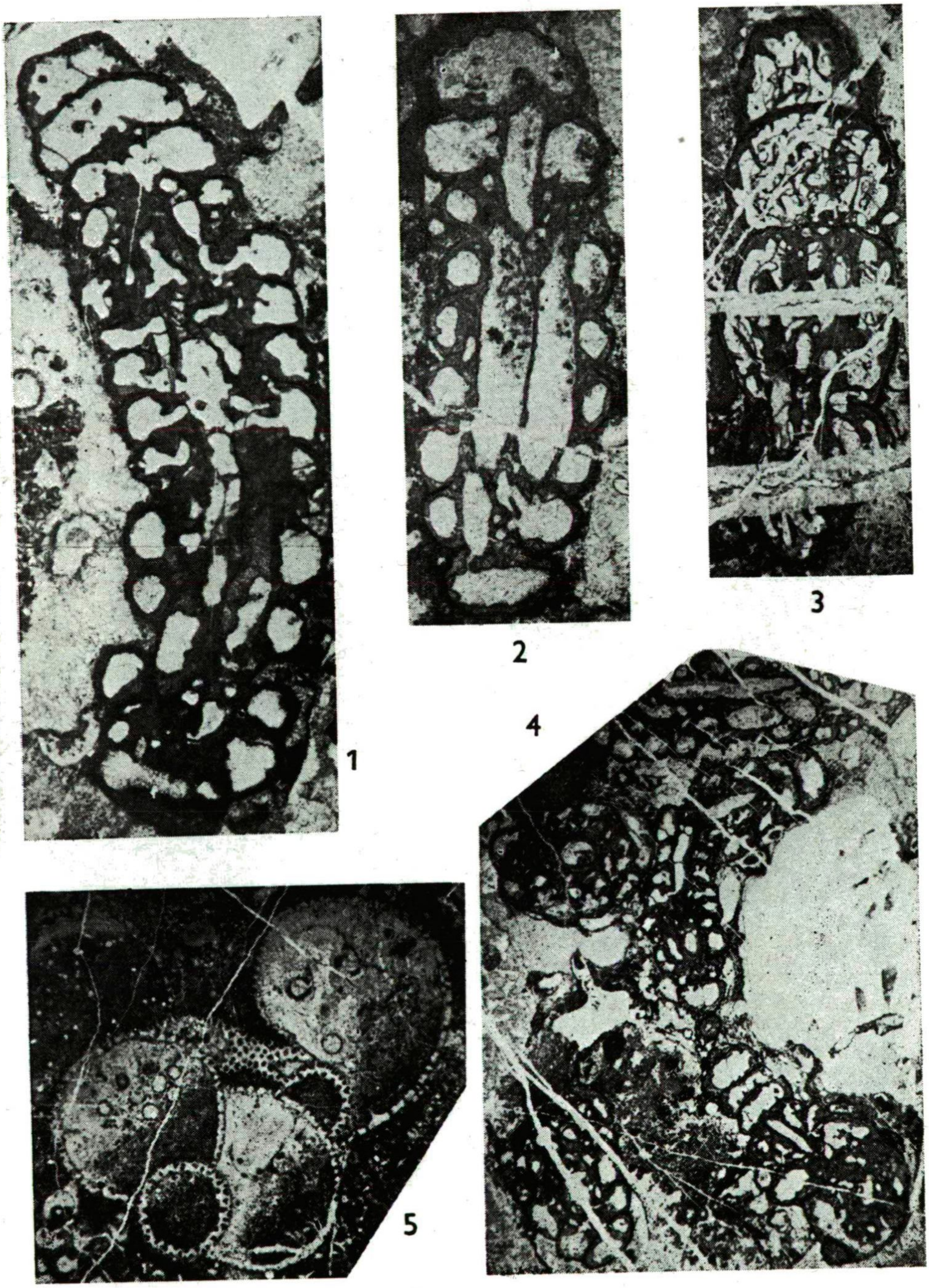

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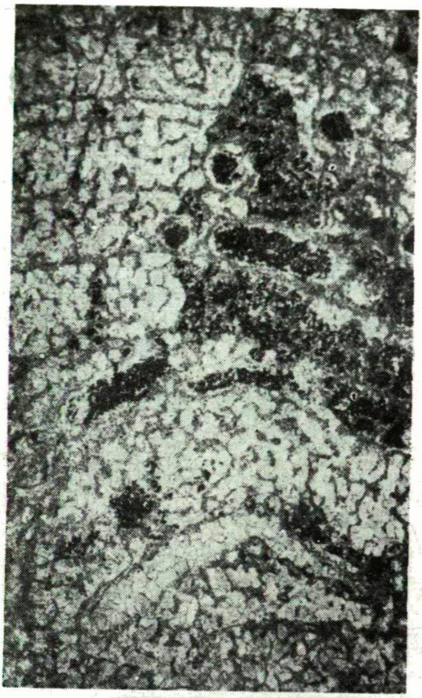

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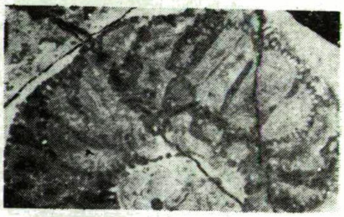

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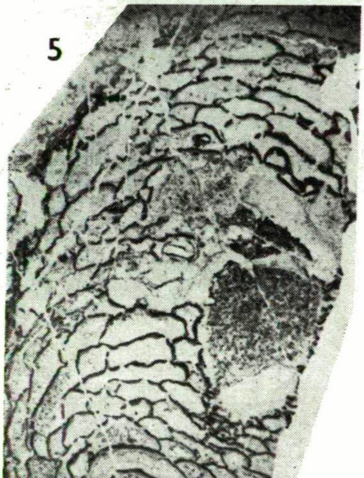

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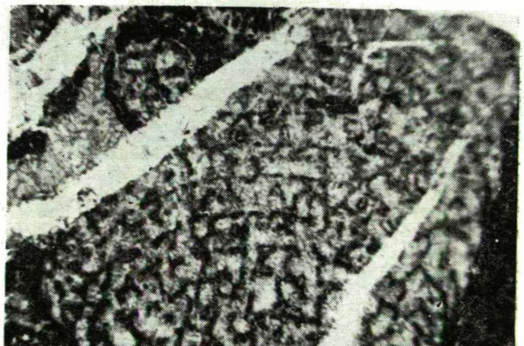

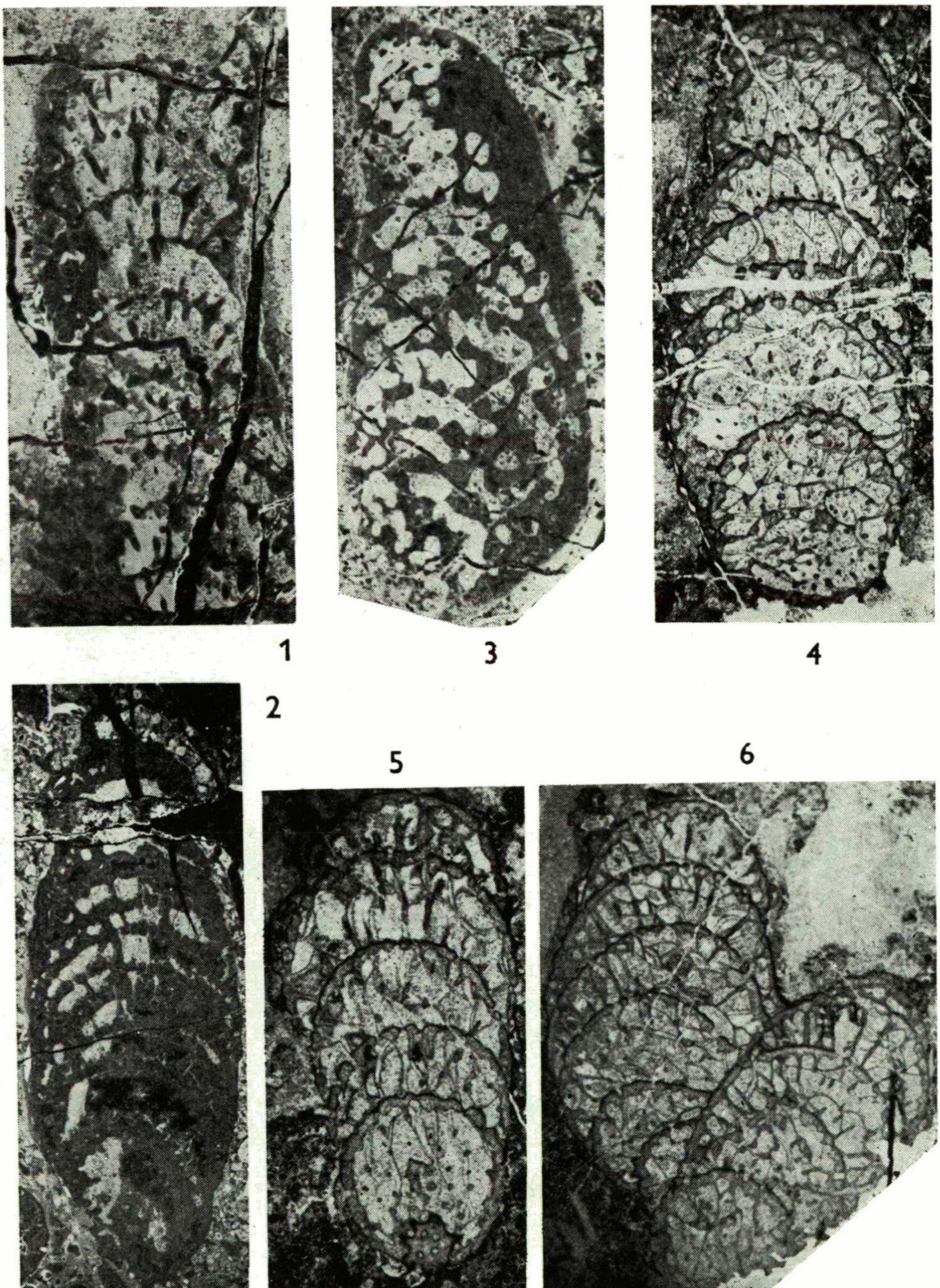
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RELATIONS BETWEEN THE CLAY MINERAL AND ORGANIC MATTER CONTENTS IN THE SEDIMENTS OF THE SOUTH GREAT PLAIN, HUNGARY

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INTRODUCTION

Our investigations aimed to find relations between the clay mineral contents and the soluble and insoluble organic matter content of rocks since these are of great importance from the points of view of formation and migration of oil.

For this purpose the core samples of the boreholes drilled in the Hódmezővásárhely—Makó Trench, *i. e.* sandstones, aleurites and clay-marls were used. The strata sequence of the boreholes Makó-1, Makó-2 and Hód-I discovered the deep-lying internal sedimentary sequences of the Neogene basin in the South Great Plain. The samples derive partly from the Upper, partly from the Lower Pannonian, as well as partly from the Miocene.

DETERMINATION AND DISCUSSION OF THE CHANGE OF MINERAL COMPOSITION

The quantitative determination of clay minerals was carried out from the fractions of less than ten microns after removing the carbonates and organic matter. The procedure was carried out by means of chemical methods. The quantities of montmorillonite, micas, chlorite, kaolinite, amorphous material, quartz, K- and Na-feldspars were determined.

The method of determination was summarized by ALEXIADES and JACKSON [1966]. The method and calculations were modified according to the problems arisen. The determination of the mica-content is based on the measurement of K-content. The quantities of quartz and feldspars were calculated on the basis of the K- and Na-content of the rest remaining after the fusion by pyrosulphate. The amorphous material was determined on the basis of the SiO_2 and Al_2O_3 content remained after the solution in 0.5 N NaOH. The determination of kaolinite is based on the difference of SiO_2 and Al_2O_3 contents occurring between the solution in 0.5 N NaOH after heating treatment at 110° resp. 585°C. The chlorite content was computed from the water content decrease following 300 and 950°C taking into consideration also the water content of the other clay minerals, as well. The determination of vermiculite and montmorillonite is based on the measurement of ion exchange capacity.

The method does not throw light upon the fact that montmorillonite is a discrete phase or it is present in form of interstratified illite-montmorillonite. Based on the X-ray diffractometric investigations carried out by J. MEZŐSI, however, in these samples montmorillonite occurs only in interstratified structure.

In the boreholes the mica and chlorite contents predominate though in some samples considerable amount of montmorillonite could also be detected. The quantity of kaolinite is small, it does not exceed 5 per cent. The quartz content varies around 20 per cent. The quantity of Na-feldspar is greater than that of the potash feldspar but remains below 10 per cent. Only the coarse detrital Miocene sediments represent exceptions in which the quantity of Na-feldspar amounts to more than 10 per cent.

The average quantities of each components were computed to the Upper, and Lower Pannonian as well as to the Miocene samples.

The Miocene samples were divided into two groups, *i. e.* the pelitic sediments between 4176 and 4565 m and the coarse-grained sediments between 4565 and 4803 m, respectively. Concerning the two types of Miocene samples, the average quantities of minerals were also computed.

TABLE 1

Average of percentual quantities of mineral components in the sediments of different ages

Sample	Na-feldspar	K-feldspar	Quartz	Amorph mat.	Kaolinite	Montmorillonite	Chlorite	Mica
Upper Pannonian	3.2	1.1	17.4	5.6	3.0	15.9	19.9	26.0
Lower Pannonian	5.1	1.4	18.4	2.7	1.4	10.4	30.2	28.0
Miocene	8.3	0.4	20.2	2.2	1.6	10.1	30.4	30.7
Miocene pelites	4.1	0.6	19.9	2.2	2.0	8.5	39.8	29.5
Miocene coarse sediments	11.4	0.3	20.4	2.1	1.2	11.2	23.5	31.8

It is worthy to note that the quantity of the minerals reflecting most sensitively the diagenetic changes, *i. e.* that of kaolinite, montmorillonite, chlorite and amorphous material, except micas, shows good agreement rather between the Lower Pannonian and Miocene, than between the Upper and Lower Pannonian samples.

Based on the differences of the average quantities of mineral components showing between the Upper and Lower Pannonian samples it would be a false conclusion that the diagenetic changes took place under relatively small depth of burial and during the subsequent burial only insignificant transformations followed since on the basis of other investigations at the boundary of the Upper and Lower Pannonian the change of the sedimentation environment and that of the source area, respectively, should be taken into account. Thus, in addition to the average values the investigation of the quantities of individual minerals as a function of depth prove to be also important.

It is to be noted here that when investigating the quantitative average values of minerals as a function of the depth it seems so that the great differences in the average values can be attributed to the change of the source area while the trends of changes can be related to the diagenetic effects in the Lower and Upper Pannonian.

The decrease of amorphous material parallel with the increase of crystallinity may also be in connection with the diagenetic transformation.

Regarding the average values of the pelites of Miocene age the diagenetic transformations are continued. If, however, we consider the dependence of depth only the continuous increase of the mica content can be proved. The quantities of other minerals and that of the amorphous material either remains unchanged or show trends opposite to those observed so far.

Since as a function of depth mica, chlorite, kaolinite and montmorillonite show the most characteristic changes, further their genetic relationships can also be assumed the mica+chlorite/kaolinit+montmorillonite quotient was also calculated.

Parallel with the increasing mica+chlorite content the quantities of kaolinite and montmorillonite decrease. Greater deviations are found only in the coarse-clastic Miocene samples.

It has been assumed that the mica+chlorite/kaolinite+montmorillonite quotient marked by K in the following, proves to be characteristic of the diagenetic transformations. In case of the K-quotient the average values as well as the depth-dependence were studied both in the Upper and Lower Pannonian and in the Miocene samples.

Similarly to the clay minerals there is a definite difference in the average values between the Upper and Lower Pannonian samples, while the average value of the Lower Pannonian and Miocene samples are in accordance. Investigating the Miocene

TABLE 2

Values of mica+chlorite/kaolinite+montmorillonite quotient (K); the regression coefficients and the value of K extrapolated to "O" m in the sediments of different ages

Sample	K average	Regression coefficient	a
Upper Pannonian	2.30	$1.77 \cdot 10^{-3}$	0.91
Lower Pannonian	4.96	$2.61 \cdot 10^{-3}$	—5.08
Miocene	4.91	$-8.09 \cdot 10^{-3}$	41.24
Miocene pelites	6.41	$-8.06 \cdot 10^{-3}$	41.24
Miocene coarse sediments	3.65	$7.34 \cdot 10^{-3}$	—30.34

pelites separatedly, the average value increases in the following order: Upper Pannonian, Lower Pannonian, Miocene pelites. To draw any kind of conclusions concerning the diagenesis itself the dependence on depth should also be investigated. In the Upper and Lower Pannonian the value of K increases parallel with the depth, but the measure of increase is different and this is fairly reflected also by the regression coefficients.

Consequently, when taking into consideration the dependence on depth it can be concluded that diagenetic changes really take place in the Upper and Lower Pannonian. It is obvious, however, that the measure of diagenesis is different in the two sub-stages. Regarding all the Miocene samples and the Miocene pelites the K-value decreases parallel with increasing depth, *i. e.* in this case the diagenesis characteristic of the Upper and Lower Pannonian, cannot be taken into account. In the coarse sedimentary Miocene samples the K-value increases parallel with the depth, but the correlation coefficient is in this case only 0.3, thus the dependence of K as a function of depth cannot be evaluated. Based on the values of K as a function of depth the value extrapolated to "0" m can be computed and this has been marked by a. These values do not really reflect the composition of clay minerals transported originally into the sedimentary basin. On the basis of the a-values it can be assumed that though the diagenetic changes should be taken into account, these changes cannot be regarded to be continuous, *i. e.* these take place in certain depth intervals but in other depth intervals these do not occur or take place only in restricted manner.

CHARACTERIZATION OF THE ORGANIC MATERIAL OF THE SEDIMENTARY ROCKS INVESTIGATED

The organic matter syngenetic to the mineral components of the sediments being either of plant or animal oiigin will be transformed during sedimentation and during the subsequent diagenesis. This transformation is essentially coalification and bituminization process which take place together in the nature. The fact that out of the processes mentioned above the coalification or hydrocarbon formation are characteristic of the given area, depends on the conditions predominating within the sedimentaiy basin, on the facies of sediments and last but not least on the composition of the starting organic matter.

Concerning the processes proceeded during transformation the investigation of the organic matter insoluble in organic solvents, *i. e.* of the kerogen may provide useful information.

It is known that three types of kerogen were distinguished by FORSMAN and HUNT [1958]:

1. *coaly type* — it resembles to the matters of peats, lignites and other coals thus it can be derived from lignine-bearing plant materials;
2. *non-coaly oil-shale type* — rich in lipids and proteins, it may be derived from algae, bacteria, etc;
3. *coaly oil shale type* — this is transition between the two previous types regarding both its origin and features.

Hydrocarbons derive from kerogens of non-coaly oil shale type. The genesis of methane, however, may be different.

To decide whether the kerogen of the core samples deriving from the deep basin parts of the South Great Plain played any role or not in the formation of the hydrocarbons discovered in the neighbouring areas, first of all the type of kerogen has to be known.

Since the composition, moreover the structure of the kerogens of different types considerably differ from each other it can be assumed that by means of determination of some characteristic functional group the possibility to classify the kerogens may be provided.

We started from the assumption that in case of kerogen of coaly type (which may derive from lignine-bearing plant material) the quantity of methoxy groups is relatively higher even if during the coalification process ever more of the about 17 per cent methoxy groups were cut during geological times. Further, knowing the geological conditions in can be assumed that the decomposition products of the plant material which got the sediments did not reach the anthracite state.

On the contrary, in case of kerogen of non-coaly oil shale type very low methoxy group content can be expected on the basis of the assumed starting organic matter.

The validity of this supposition is probabilized by the investigations of SEMENOV *et al.* [1955]. Among others, they determined the methoxy group content of the kukersite kerogen of Estonia and this proved to be about 0.2 per cent.

It is to be noted, however, that in addition to the percentual determination of the methoxy group in possession of the C- and H-contents of the kerogen and of their quotient further evaluations of different points of view are provided.

Our investigations were carried out on the organic matter extractable by organic solvents, *i. e.* on bitumen as well as on kerogens remaining after the removal of mineral components by means of chemical methods. The determination of the methoxy groups was carried out by the method suggested by ZEISEL and modified by us.

The quantity of the methoxy groups varies between 2.48 and 1.60 per cent in the Lower Pannonian sediments of the investigated section of the Hód-I borehole (2885-5812 m). Its value is 1.14 per cent in the lowermost sample which may be assigned to the Lower Pannonian while in the Miocene sediments values between 0.78 and 0.32 per cent were found.

In the core samples of the borehole Makó-2 considerably smaller deviations were found in the methoxy group contents of the sediments of different ages. It varies between 1.65 and 1.18 per cent in the Lower Pannonian and between 0.64 and 0.27 per cent in the Miocene. The values of the two samples lying at the boundary of the Miocene and Lower Pannonian proved to be 1.28 resp. 1.57 per cent.

Without trying to draw definite limits among the types of kerogen on the basis of the percentual quantity of the methoxy groups or assign the kerogen of the investigated sediments into groups only on the basis of these data, the following is to be noted. In case of both boreholes the organic matter of the younger sediments is rather of plant origin resp. the coalification processes had been of predominating role in its transformation. In the older sediments, however, the original organic matter had been of other composition and the bituminization processes predominated in its transformation.

Further, on the basis of the quantity of methoxy content the insoluble organic matter of the core samples can be assigned to the group of kerogens of coaly oil shale type. It is to be noted, however, that in this case the kerogen of the core samples of Miocene age ought to be assigned to the group of kerogens of non-coaly oil shale type, this is to be verified, however, by the investigations to be done.

In the course of transformation of kerogen soluble organic matter also develops, consequently the soluble organic matter content (in the following bitumen) of the rock samples was also analysed.

The bitumen content was extracted in Soxhlet apparatus. Subsequent extraction was applied: first the ground rock sample was extracted by chloroform in order to get the Bit-A, then having treated the sample with hydrochloric acid the benzene-ethanol extraction was carried out. The extract obtained in this way is the Bit-C.

The extracts Bit-A and Bit-C were divided into three fraction by means of column chromatography.

In the sedimentary rocks of the "Hódmezővásárhely—Makó" Trench the Bit-A content varies between 0.020 and 0.249 per cent. Its value shows increasing trend as a function of increasing depth. This is in harmony with the statement of EREMENKO, *i. e.* the quantity of the neutral bitumen increases with the increasing age. The value of Bit-C changes nearly in the same interval with the only difference that the trend of change proves to be decreasing as a function of depth. This can be related probably to the gradual transformation of the organic matter.

Investigating separatedly the quantities of Bit-A for the Upper and Lower Pannonian it can be stated that its value hardly changes in the Upper Pannonian, while it shows increasing values as a function of depth in the Lower Pannonian.

The changes observed in the Miocene rock samples of the boreholes Hód-I and Makó-2 relate to two different petrological formations. In the borehole Hód-I the pelitic sequences predominate, while in the borehole Makó-2 coarse clastic formations were found. The quantity of Bit-A increases in the Hód-I samples and decrases in the Makó-2 samples when regarding only the Miocene sequence.

The increase following in the Lower Pannonian may be in connection with the more progressed measure of the continuous transformation of the organic matter and with the strengthening of the secondary character of Bit-A.

When grouping the changes of the Bit-C values also according to geological ages the following statements can be made: in the Upper Pannonian its quantity increases, in the Lower Pannonian it shows decreasing tendency, in the Miocene, however, changes of different character can be observed, similarly to those found in case of Bit-A. During the Miocene the quantity of Bit-C increases in the Hód-I samples and decrases in those of Makó-2. This change can be probably explained by the different measure of the Bit-C → Bit-A transformation as well as by the different petrological formations of the two sequences.

According to the investigations of Tissot [1971] the quantity of the hetero--compounds of great molecular weight decrases as compared to that of the compounds poor in hetero-atoms or containing no heteroatoms. He assumed that the following transformation takes place: kerogen → compounds containing O, N and S hetero--atoms (acid bitumen) → hydrocarbons, resins, asphalts (neutral bitumen).

The experiments carried out by Louis and Tissot [1967] on the samples of the Paris Basin relate also to such transformation. In the course of experiments the samples were treated under such pressure-temperature conditions which prevail in the deepest part of the basin. They observed the increase of the quantity of netural bitumen and assumed that this proceeds through the formation of the acid bitumen.

In our investigations the Bit-C corresponds to the acid, the Bit-A to the neutral bitumen, thus according to Tissot the kerogen → Bit-A → Bit-C transformation was assumed.

On the basis of the core sample investigations, however, this transformation cannot be so unambiguously followed. The quantity of the Bit-A and Bit-C of each samples is affected by the environmental factors, by the quantity of the organic matter got the sediments, by its quality and by the possible migration. Taking into account all these factors it can be stated that the change of the Bit-C value may in connection with consecutive character of the transformation itself. In the Upper Pannonian the kerogen → Bit-C, while in the Lower Pannonian the Bit-C → Bit-A transformations might prevail. The change followed in the Miocene samples of the borehole Hód-I may relate to the acceleration of the Bit-A-formation process.

The average quantities of bitumens (regarding both Bit-A and Bit-C) are considerably higher in the core samples of the borehole Hód-I than in those of Makó. This difference in quantities can be deduced from the positions of the boreholes in the sedimentary basin. On the basis of the borehole Hód-I. in the Hódmezővásárhely-Makó trench a hydrocarbon-bearing pelagic facies of negative redox potential prevailed with a water depth of several hundred metres.

The boreholes of Makó show littoral characteristics while the borehole Hód-I shows farther and deeper features on the basis of bitumen content, too.

The formation of the quantities of Bit-A and Bit-C was explained by the thermal degradation of the organic matter. To explain the changes, however, it is insufficient to take into consideration only the chemical transformations since other factors may also play important role in the qualitative formation of the organic matter, as has been mentioned earlier, as well. One of the most important factors is the migration, thus in the course of our investigations we tried to throw light upon the primary or secondary character of the organic matter.

As to our assumption, to decide the primary or secondary character of the organic matter the quotient Bit-C/Bit-A together with the Bit-A and Bit-C values can be used. Since Bit-A consists of much more mobile components, the Bit-A values have to show maxima in the sites where the organic matter can be considered to be secondary *(Fig. 1.)*.

Due to its more polarized character the Bit-C is able to adsorption, *i. e.* it is bound rather to the place of formation, consequently it can be assumed that its greater quantities relate to the primary character of the organic matter. If this assumtion can be accepted within certain limits, the value of the Bit-C/Bit-A quotient will be low in case of secondary organic matter and will high in case of primary organic matter. This can be in connection with the mobility of Bit-A and immobility of Bit-C, respectively. The quotient itself alone is, however, insufficient to decide this problem. In case when the Bit-A value is high, but that of Bit-C is also high, *i. e.* the value of the quotient does not differ from the average it is less probable that in the samples there is an organic matter of secondary character (though the value of the quotient relates to this fact). Thus, taking into account the values of Bit-A and Bit-C it can be stated that high Bit-C/Bit-A quotient relates to the primary, the low one to the secondary character of the organic matter. Organic matter of ideally pure primary and pure secondary character was found in no core samples, consequently the denomination of primary and secondary denote a predominantly primary and predominantly secondary character. Between these two extreme states an intermediary group can be distinguished which, on the basis of the relative values of Bit-A and Bit-C can be assigned to the groups of "rather primary" resp. "rather secondary".

Taking all these into consideration it can be stated in general that the organic matter is rather of primary character in the Upper Pannonian, and rather of secondary character in the Lower Pannonian.

In case of the Miocene samples, however, the differences observed so far, also occur. In the Miocene core samples of the borehole Hód-I predominantly primary organic matter was found while in those of the borehole Makó-2 the organic matter of primary character becomes predominant only in a depth below 4560 m. Between 4560 and 4160 m, *i. e.* to the Lower Pannonian — Miocene boundary, the organic matter is mostly of secondary character. It is worthy of note, however, that in the borehole Hód-I the organic matter of primary character becomes predominant nearly in the same depth interval (4540—4880 m).

As it has been mentioned earlier, according to the transformation kerogen → Bit-C → Bit-A, a genetic relation between Bit-A and Bit-C can be assumed. Due to other factors influencing the quantity of the organic matter, this relation cannot be unambiguously followed.

On the basis of the factors used to distinguish the primary and secondary character of the organic matter and taking into account only the samples of primary organic matter content, a relationship was found between Bit-A and Bit-C.

The points lie on a straight line when plotted Bit-A against Bit-C *(Fig. 2.)*.

In case of the borehole Hód-I the samples containing primary organic matter lie along two straight lines. Taking into account the distribution according to ages it can

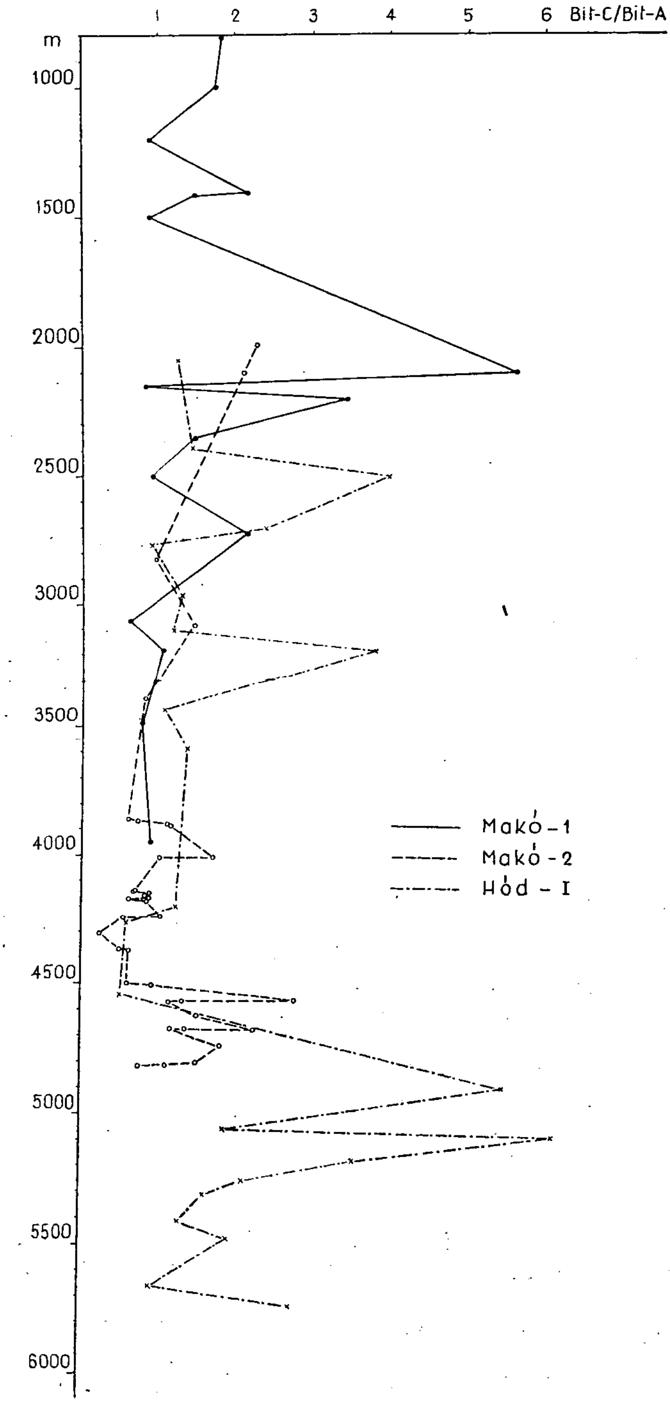

Fig.1. Dependence on depth of the Bit—C/Bit—A

be stated that the Miocene samples lie along the line of steeper rise, the samples deriving from the Lower Pannonian, however, lie along the line of less steeper rise.

In the borehole Makó-I the samples of Upper and Lower Pannonian ages were investigated. In case of the samples being assigned to the Upper and Lower Pannonian the rise of the straight lines is nearly the same and this may relate to a hydrocarbon genesis of similar character.

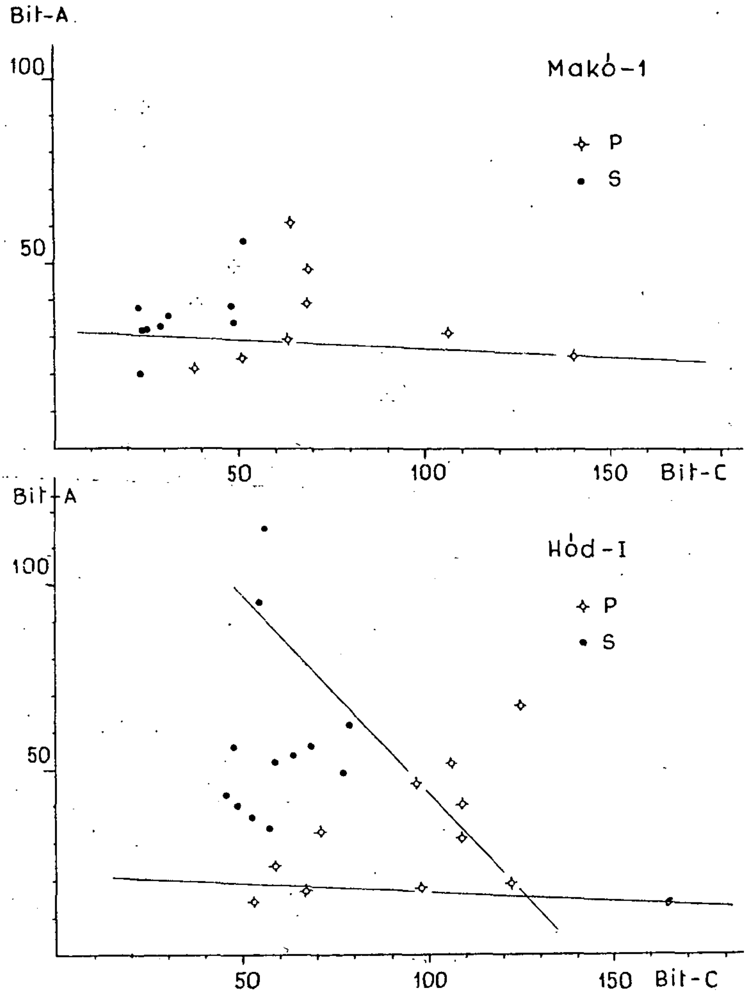

Fig.2. Change of Bit—A against Bit—C

On the basis of the two lines obtained for the core samples of the borehole Hód-I it can be assumed that hydrocarbon genesis of different character proceeded in the Miocene and in the Lower Pannonian.

Due to the migration of the organic matter not only the value of the Bit-C/Bit-A quotient will change but a relative difference in the bitumen composition also occurs.

This can be explained by the differences in mobility of the three fraction obtained in the course of column chromatographic separation of bitumen (in the first fraction the hydrocarbons, in the second the neutral resins, in the third the acid resins are found). It is to be noted here, that the separation by means of column chromotagraphy was carried out in the samples where this proved to be possible from the quantity of the organic matter.

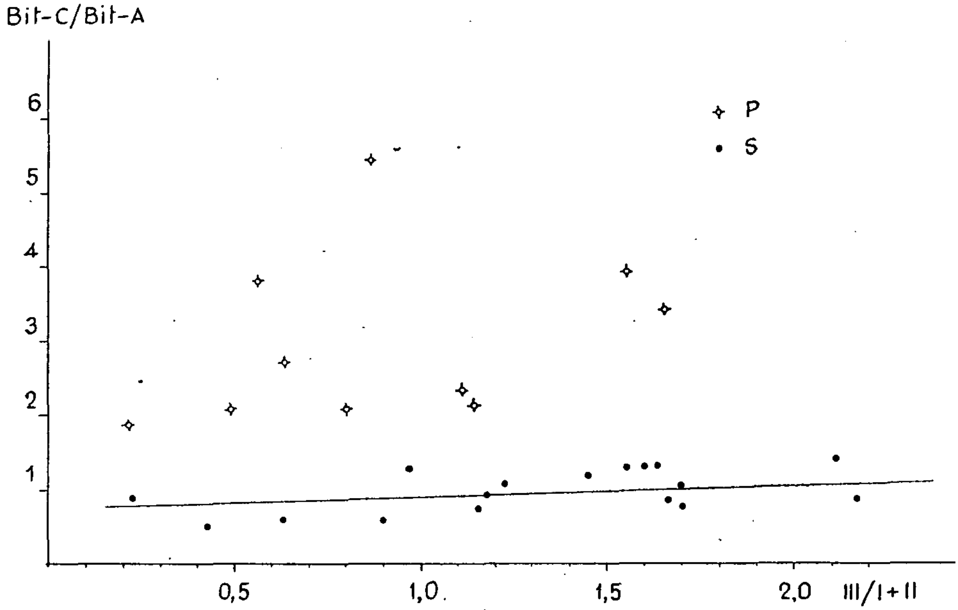

Fig.3. Relations of Bit—C/Bit—A and of the quotients of fractions obtained by column chromatography

According to our investigation results to separate the primary and secondary character of bitumen the column chromatographic fractions can also be used in addition to the quantity of the chloroform soluble bitumen. On the basis of these factors and of theoretical considerations the Bit-C/Bit-A quotient should be in relation with the quotient obtained from the fractions III/I+II.

When plotting the Bit-C/Bit-A quotient against the fractions III/I+II the core samples containing the organic matter of secondary character lie along one line in case of both boreholes and this may verify the relation between the two quotients in the changes during migıation. *(Fig. 3.)*

As to our assumption the organic matter content of the core samples is in connection with the clay mineral content.

Since the adsorption capacity of the clay minerals is determined by their cation exchange capacity (in the flolowing CEC), the change of the Bit-A and Bit-C was investigated as a funct'on of CEC. The relat'on between the B'it-A and CEC verifies our assumption on the separation of primary and secondary bitumens. Relation between the two parameters may exist only in the samples which contain primary bitumen. In case of the samples, however, the Bit-A might emigrate, thus between Bit-A and Bit-C there may be a relationship that all the primary Bit-A lie on a line of certain rise and on the are a under this line respectively, when plotted Bit-A against CEC *(Fig. 4.)*.

As it was expected, between the CEC and Bit-C containing the polar groups in greatest quantity there is an unambiguous relationship: the quantity of Bit-C increases parallel with the CEC. Some of the samples show irregular behaviour, *i. e.* the

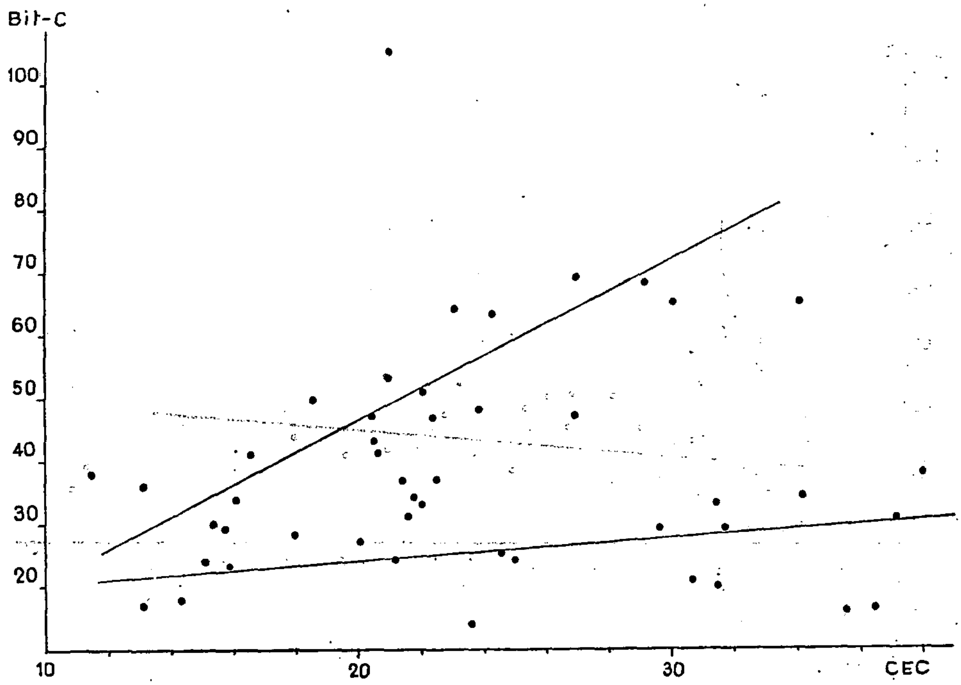

Fig.4. Relation between Bit—C and CEC (cation exchange capacity)

quantity of Bit-C increases parallel with the CEC but this increase is of smaller measure than that observed in major part of the samples. This double distribution can be explained neither by the difference in the rock types, nor by the geological ages.

Further, the change of the quantity of the soluble organic matter was investigated as a function of the *K*-quotient characteristic of the diagenesis of clay minerals *(Fig. 5.)*.

Part of the samples shows exponential increase with increasing *K*-value, the other part shows linear increase in the Bit-C quantity. The Upper Pannonian samples lie on the exponential, the Lower Pannonian and Miocene lie on the linear line.

The sharp difference between the Lower Pannonian and Miocene and Upper Pannonian samples, respectively, is reflected also by the geological conditions. On the basis of the macroscopic description the Upper Pannonian samples contain brown coal strips, humic substance and plant remnants. It can be assumed that in the Upper Pannonian a coal-forming while in the Lower Pannonian a sapropelic facies can be expected.

The exponential and linear character of the changes observed in the Upper

Pannonian, Miocene and Lower Pannonian samples respectively, can be explained by the difference of microbiological activity between the coal-forming and sapropelic facies.

The exponential change observed in the Upper Pannonian can be probably explained by the fact that in case of coal formation organic matter develops which restrain the diagenetic transformation of the clay minerals.

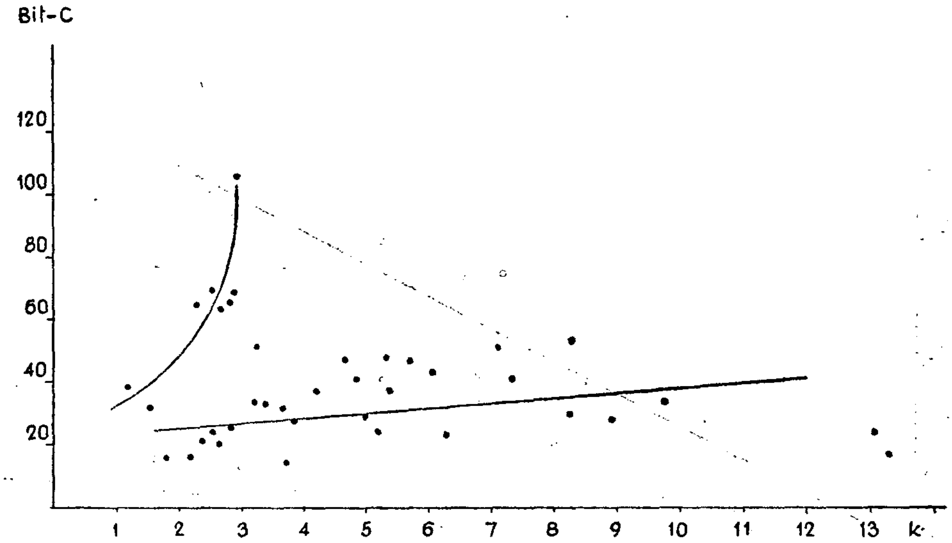

Fig.5. Relation between Bit—C and the quotient mica + chlorite/kaolinite + montmorillonite *(K)*

CONCLUSIONS

When evaluating the results of investigations, the following conclusions can be drawn:

1. On the basis of the dependence on depth of the quantities of each clay minerals, as well of their mutual relations diagenetic transformations can be assumed in the area in question. In the course diagenesis the mica and chlorite contents increase while the kaolinite and montmorillonite contents decrease, thus the *K*-quotient can be used to characterize the grade of diagenesis.

2. The quantity of the methoxy groups, together with the C- and H-contents and with their quotients allow to draw conclusions to the degree and character of the transformation.

3. A genetic relationship can be assumed between Bit-A and Bit-C, according to the transformation kerogen → Bit-C → Bit-A. As to our investigations the transformation cannot be unambiguously followed since in certain samples the quantities of Bit-A and Bit-C are highly affected by environmental factors, by the quality of the organic matter of the sediments, and by the possible migration.

4. It is assumed that to determine the character of the organic matter the Bit-C/Bit-A quotient resp. the Bit-A and Bit-C values can be used.

5. There is a relationship between the bitumen content and the cation exchange capacity of clay minerals influencing their adsorption capacity. This relationship verifies that the organic matter is bound to the fine-grained clayey components.

REFERENCES

ALEXIADES, C. A., M. L. JACKSON [1966]: Quantitative clay mineralogical analysis of soils and sediments. Clays and Clay Minerals *14*, 35-52.

FORSMAN, J. P., J. P. HUNT, [1958]: Insoluble organic matter (kerogen) in sedimentary rocks. Geochim. Cosmochim. Acta *15*, 170—182.

TISSOT, B. [1971]: Die Bildung von Kohlenwasserstoffen beim termischen Zerfall organischer Substanz. Zeitschrift für angewandte Geologie *17*/10, 406-410.

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IAGOD COMMISSION ON MANGANESE
IGCP PROJECT No. 111: GENESIS OF MANGANESE ORE DEPOSITS
NOTES and NEWS

Brief Summary of Papers Presented at Technical Sessions of the Commission on Manganese, Snowbird, August, 1978

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The Commission was alloted time for two technical sessions. During the first, held Thursday, August 17, the first paper was presented by DR. ROGER KEY, of Botswana. He reported on *"The Stratabound Manganese Deposit of the Palapye Group, Botswana"*. The manganiferous beds are clastic sedimentary rocks which have a maximum thickness of ten metres and have been traced almost continuously along the strike for 48 kilometers. At depth the Mn content is low, but near-surface enrichment has produced a zone as deep as 1.5 metres which in places contains as much as 70.2 percent MnO_2. Diamond drilling suggests that enrichment in Mn has only a minor downdip development.

The second paper was delivered by DR. SUPRIYA ROY, of India, and was entitled *"Sedimentary Ore Bodies from the Upper Proterozoic Penanga Sequence, Andhra Pradesh, India"*. Manganese oxide ore bodies, some with nodular masses resembling modern deep sea nodules, some with manganese oxides interbedded with jasper (called "manganese-formation", in allusion to the similarity to Lake Superior-type "iron-formation"), occur interstratified with magnesian limestones, chert, jasper, and limey shale over an area greater than 200 square kilometers. Oxides interlaminated with jasper consist of todorokite, pyrolusite, and braunite, whereas ore interbedded with magnesian limestones contain ramsdellite-nsutite and birnessite-rancieite-todorokite. The deposits are considered to be of sedimentary origin partially altered during diagenesis.

DR. EUGENE ALEXANDROV, of the United States, then discussed the large-scale relationships of sedimentary manganese deposits throughout geologic time in a paper entitled *"The Genetic Convergence of Sedimentary Manganese Deposits"*. His thesis is that a metallogenic epoch, concordant with a sedimentary sequence (time-stratigraphic unit), is characterized by deposits of economic importance, low-grade deposits, and by rocks with a somewhat higher than clarke level concentrations of manganese (the two latter may be called embryonic metallogenic epochs). The accumulation of manganese in a particular time-stratigraphic unit is controlled by the environmental conditions in a given metallogenic province, and is, in principle, independent of the genetic nature of the source of the manganese. Examples from Europe, Asia, and the Americas were given, and it was suggested that an attempt be made to seek world-wide correlations of manganese deposits in sediments.

The business meeting of the Commission on Manganese was held after the last paper. The results of the meeting are summarized in a separate report.

The second technical session was held on Friday, August 18, and began with a presentation by DR. D. S. CRONAN of the paper *"Geochemistry of Ferromanganese*

Oxide Deposits from the Northwest Indian Ocean". He compared the composition of samples both from the volcanically active Carlsberg Ridge and from an adjacent range of inactive seamounts. Bulk Mn content of the Carlsberg Ridge samples was somewhat higher than in the seamount collection, but there are few significant differences between the concentrations of the other elements analyzed (Fe, Co, Ni, and Pb). Electron microprobe analyses showed distinct compositional banding in one of three samples analyzed. The variations are interpreted to indicate considerable changes in the depositional environment during the growth of this encrustation.

DR. SUNIT ADDY, also of the Unites States, then reported on the *"Manganese Nodule Deposits in the Northwest Atlantic: Their Distribution, Origin, and Prospect"*. The nodule deposits in question are in the region between 25° 30′ and 29° 30′ north latitude and 58° 00 west longitude, in the abyssal hillregion of the Atlantic Ocean. The area is dominated by three deep turbidite-filled fracture valleys in the center. Mn nodules are found in varying concentrations on the abyssal hills and are absent in the fracture valleys. Maximum concentration of nodules is found between depths 5000 and 5300 meters, where the average concentration was found to be 0.75 gm/cm^2. The oxide phase in the nodules consists of birnessite and colloidal iron oxides. The detrial phase has mineralogy similar to that of the red clay substrate. Average composition of the nodules in weight percent, is 15.07 Fe, 13.03 Mn, 0.33 Ni, 0.30 Co, 0.14 Cu, and 0.057 Zn. The concentration of thorium averages 130 ppm. REE content is low compared to Pacific nodules, but relative concentrations are similar to the pattern in Pacific nodules. The Fe/Mn ratio and trace element geochemistry indicate that the nodules are predominantly hydrogenous. The deposits are not presently of economic quality, but the area is estimated to contain 240 million metric tons of nodules.

The third paper, presented by WILLIAM REINHART, of the United States, was entitled *"Metal Variations in Pacific Manganese Nodules from a Potential Deep Sea Mining Area"*. The area in question is at approximately 15° 10′ north latitude, 126° west longitude, in the DOMES Site C locality. XRF analyses were reported for Mn, Fe, Ni, Cu, Co, and Zn for 159 nodules selected from 21 box cores. Nodules representative of each box core were chosen according to size, shape, and surface texture, and chemical variations were found to be somewhat greater within some box cores than from one box core to another. Average composition (weight percent) for the entire group of 159 nodules, with first standard deviation for each element, was calculated without regard for nodule size, as: Mn 25.31 ± 4.34, Fe 6.82 ± 1.32, Ni 1.27 ± 0.16, Cu 0.88 ± 0.23, Co 0.28 ± 0.05, and Zn 016 ± 0.05. Among the box cores which contained nodules of greatly different size, small nodules (less than about 4 cm in length) generally contained higher percentages of Mn, Ni, Cu and Zn and lower percentages of Fe and Co than larger nodules. Detailed bottom topography shows that the smaller nodules are commonly more abundant on hill crests and side slopes than in depressions, where large nodules commonly are abundant. The chief factors which influence nodule composition were found to be proportions of different types order and proportions of oxides relative to rock or clay. Nodule fragment cores predominate in the small nodules of the suite studied. In the larger nodules, clay cores are fairly common.

The fourth paper, presented by R. K. SOREM, of the United States, described observations and speculations on the physical environment of deep sea nodules and was entitled *"Nature and significance of a diffuse sediment-water interface 'boundary layer' in East Pacific manganese nodule deposits"*. The observations included the appearance of manganese nodules and the associated sediment in bottom photographs and box cores obtained during the Deep Ocean Mining Environmental Studies (DOMES) project of the U.S. National Oceanic and Atmospheric Administration (NOAA) in 1975 and 1976. Attention was called to the fact that bottom photographs show that nodules in some places are sharply outlined and seem to rest on a relatively firm substrate, whereas in other places they have a hazy outline and may be surrounded partly by a thick suspension of mud and water. Many photographs show the weak nature of this "boundary layer" by recording the effects of the camera compass as it approached or struck the bottom. The boundary layer is destroyed during collection of most box cores, but in several cores attempts to preserve it by gelling the supernatant water were partially successful. It was proposed that the presence of this sediment-rich interface boundary layer (never more than a few cm thick) of water promotes the precipitation of hydrous Mn oxides, the chief Ni- and Cu-bearing components of manganese nodules, by catalyzing the oxidation of Mn^{+2} in the manner proposed by HEM in 1963 on the basis of laboratory experiments. The slow lateral movement of such a layer could account for alternating layers or shells of crystalline Mn-rich oxides and X-ray amorphous Fe-rich oxides during nodule accretion, for nodules of a certain size ((perhaps larger than 4 cm) would tend to be covered during some periods, uncovered and exposed to sea water during others.

The next paper presented by V. P. RAKHMANOV (USSR) was concerned with localization of manganese, ferromanganese, lead, and lead-zinc ores in carbonate sediments. The paper, entitled *"Manganese ores in activated platforms"*, discussed the role of deep sub-latitudinal faults and fault conjunctions in the accumulation of metalliferous formations in the Upper Devonian of Central Kazakhstan (USSR) and at the base of the Upper Cretaceous of South Morocco. The Uspenskaya tectonic zone (USSR) extends 450 km and includes abundant sheet-like iron-manganese-barite-lead-zinc deposits in siliceous-calcareous and calcareous strata. This linear geostructure is believed to have formed in the Caledonian folded basement in the Early Hercynian epoch. In Morocco, the syngenetic lead-bearing manganese ores formed in Cenomanian-Turonian dolomites in the zone of conjunction of the Anti-Atlas (south Morocco) with the southwestern mobile branches of the High Atlas, a zone more than 100 km long. In both regions, the tectonism and igneous activity in the active zones were accompanied by basaltic eruptions. It is concluded that the metallic concentrations formed in many steps and that in some epochs metal deposition was related to tectonism.

Several other papers were submitted and accepted for inclusion in the Commission on Manganese Technical Sessions but for various reasons could not be presented with the others. The abstracts are published in the Program and Abstracts volume of the Snowbird meetings. The papers include:

CHUKHROV, F. V.: Some problems of ocean ore genesis.

HALBACH, PETER: Terrestrial formation of manganese and iron precipitates in northern latitudes.

LALOU, CLAUDE, and BRICHET, EVELYNE: Radiochemical, microchemical, and structural study of a manganese nodule from the North Pacific.

VARENTSOV, I. M.: The metalliferous sediments in Cenozoic history of sedimentation, near the crest of the Mid-Atlantic Ridge, Latitude 22°: Geochemistry and processes of formation.

ZANTOP, HALF: Trace elements in continental-volcanic iron oxides and manganese oxides: The San Francisco manganese deposit, Jalisco, Mexico. (Note: this paper was formally withdrawn by the author but was printed by the Program Committee, IAGOD).

REPORT ON BUSINESS MEETING
IAGOD COMMISSION ON MANGANESE – SNOWBIRD, UTAH

17 August 1978

by RONALD K SOREM

Members of Commission and Visitors in Attendance —

D. S. CRONAN, U. K.
S. ROY, India
R. SOREM, USA
B. MIKHAYLOV, USSR
V. RAKHMANOV, USSR
S. K. ADDY, USA
E. ALEXANDROV, USA
A. K. BANERJI, India
T. TATSUMI, Japan
W. ZIMMERNINK, FRG
W. MEYER, Canada
R. KEY, Botswana
E. VON BRAUN, UNESCO, IGCP Secretary

Agenda and Action

1. DR. VON BRAUN: Introductory comments on behalf of International Geological Correlation Programme Secretariat.
2. Reports on Commission activities since Sydney meetings.
   A. Collection, editing, and publishing manuscripts from 2nd Manganese Symposium (Sydney) in 3-volume "International Monograph on Geology and Geochemistry of Manganese", Editor-in Chief,I. M. Varentsov.
   Publication dates: Vol. 1: Late 1979
   Vol. 2: First half of 1980
   Vol. 3: First half of 1980
   B. IGCP Proj. No. 111 (see attached report).
3. Preliminary discussion for organization of Third International Manganese Symposium, to be held during 26th International Geological Congress, Paris, 1980. DR. CRONAN will make the necessary arrangements with DR. GRASSELLY (already invited by Z. JOHAN) and DR. JOHAN, co-organizer of Section 13, 26th IGC to develop the program. It was agreed that sessions on several days would probably be necessary for technical papers.
4. Announcement of resignation of DR. GRASSELLY as President of the Commission on Manganese and Leader of IGCP Project No. 111. An unanimous vote was made to express deep appreciation for DR. GRASSELLY's leadership and efforts in the past, and all present wished him a speedy and complete recovery from his recent vertebral injury. DR. GRASSELLY will remain active as Past-President and as a scientist in Proj. No. 111 work. It is hoped that he will continue his efforts to encourage and carry out a program of technical cooperation with developing countries through IGCP Proj. No. 111.
5. Election of officers. DR. CRONAN was elected our new President of the Commission on Manganese by acclamation. He accepted and nominated DR. SUPRIYA ROY as Leader of IGCP Proj. No. 111. DR. ROY was elected by acclamation and also accepted. DRS. CRONAN and ROY will work together very closely, but the separation of the Project leadership from the President's office is expected to lighten appreciably the President's responsibilities, which heretofore have been very heavy.

DR. I. M. VARENTSOV is requested to continue as Secretary of the Commission and Scientific Coordinator of Project No. 111, posts he has filled with great vigor and devotion. DRS. ROY and SOREM will continue to serve as Vice Presidents of the Commission.

6. Future activities. It was agreed that the two principal activities of the Commission during the next two years will be:

A. Plan and carry out meetings of the third International Manganese Symposium at the 26th IGC in 1980.
B. Arrange for publication of the proceedings of the Third Symposium.
C. Promote activity of all panels in IGCP Project No. 111 and arrange for technical sessions to report progress at 26th IGC.
D. Hold extensive discussions on progress and future activities of Project No. 111 panels, with emphasis on international cooperation.

26e CONGRÈS GÉOLOGIQUE INTERNATIONAL
26th. INTERNATIONAL GEOLOGICAL CONGRESS

SECRÉTARIAT GÉNÉRAL

ANNOUNCEMENT CONCERNING 26th INTERNATIONAL GEOLOGICAL CONGRESS

Sessions of the International Geological Congress have been held every four years since 1878. The 26th session will celebrate the Centenary of this organization convened under the auspices of the International Union of Geological Sciences.

Organization Committee: Chairman: Jean AUBOUIN
Secretary General: Paul SANGNIER

Timetable: — 26 June to 5 July — Pre-congress scientific excursions
— 7 to 17 July — The Congress will meet at the Palais des Congrès at Porte Maillot
— 18 to 37 July — Post—Congress scientific excursions.

Scientific Program

1) *Opening Scientific Meeting:* Leading specialists will survey five main themes concerning the current state of scientific progress.

2) *Sections:* The proposed program covers almost the entire field of the Earth Sciences and is divided into 20 sections. The Organization Committee has also planned to have the work of the various international scientific organizations affiliated with the International Union of Geological Sciences integrated into the program of the Congress. Authors are free to choose their own subjects for communications and these should be sent to the Secretary General before 1 October 1979 for the publication of abstracts.

3) *Colloquia:* The program for the colloquia was chosen so as to illustrate the main themes of current scientific and economic interest. There will be seven in all and the will be chaired by leading scientific figures. Communications to the Colloquia are made by invitation only.

Excursions

The Organization Committee in association with the National Committees for Geology of 18 European countries has organized an attractive program of geological excursions. The chosen themes make it possible to offer Congress participants a survey of all aspects of the geology of Western Europe. 85 different excursions each lasting for 9 days are planned from 26 JUNE to 6 JULY 1980 or from 19 JULY to 26 JULY 1980. Since only a limited number of persons can participate in the excursions the places will be reserved by the Organizing Committee in October 1979 in the order in which the reservation forms were received.

Exhibition

An exhibition to be called "GEOEXPO 80" will be held in the same premises as the Congress from 7 to 11 July 1980. It will be open to all international institutions and will make it possible for exchanges of ideas and contacts to take place with scientists from all over the world.

Social Program

Since the Congress is taking place in Paris the organizers will be able to plan a very attractive program for the participants and a special program for persons accompanying them.

State of Advancement of Congress Preparation

80,000 copies of the first circular were sent out in October 1977. By 1 December 1978 the Organization Committee had received 5,800 answers from 114 different countries and 4,000 persons had asked to take part in the excursions. The second circular is now available and contains the final registration form.

Those interested in participating in the Congress and wishing to receive the second circular should request it from the:

Secretariat Général du 26ème Congrès Géologique International
Maison de la Géologie
77—79, rue Claude Bernard
75005 PARIS — FRANCE

Le Congrès Géologique International tient ses sessions les quatre ans depuis 1878. La 26ème session sera la célébration du centenaire de cette manifestation sous l'égide de l'Union Internationale des Sciences Géologiques.

Comité d'organisation: Président: Jean AUBOUIN
Secrétaire Général: Paul SANGNIER

Calendrier:
— du 26 juin au 5 juillet excursions scientifiques pré-congrès
— du 7 au 17 juillet séances du Congrès au Palais des Congrès de la Porte Maillot — Paris
— du 18 au 27 juillet excursions scientifiques post-congrès.

Programme scientifique

1°) *Séance scientifique d'ouverture :* Cinq grands thèmes concernant l'actualité scientifique récente feront l'objet d'une synthèse par les plus éminents spécialistes.

2°) *Sections :* Le programme scientifique qui est proposé couvre pratiquement l'ensemble du domaine des Sciences de la Terre et est réparti au sein de 20 sections. Le Comité d'organisation s'est également assuré que les travaux des différentes associations scientifiques internationales, affiliées à l'Union Internationale des Sciences Géologiques soient intégrés dans le programme du Congrès. Les propositions de communications sont libres et doivent être adressées au Secrétariat général avatn le 1er octobre 1979 pour étre publiées dans le volume des résumés.

3°) *Colloques :* Le programme des colloques a été retenu pour illustrer les principaux thèmes d'actualité scientifique et économique du moment. Ils seront au nombre de 7, et seront animés par lex scientifiques figurant parmi les plus illustres. Les communications ne pourront se faire que sur papiers invités.

Excursions

Le Comité d'organisation s'est assuré le concours des Comités nationaux de géologie de 18 pays européens différents pour présenter un programme attractif d'excursions géologiques. Les thèmes retenus permettent de proposer aux membres du Congrès l'ensemble des aspects géologiques de l'Europe de l'Ouest. C'est ainsi qu'environ 85 excursions différentes, d'une durée de 9 jours chacune sont proposées, soit du 26 JUIN au 6 JUILLET 1980, soit du 19 JUILLET au 26 JUILLET 1980. Les excursions ne pouvant recevoir qu'un nombre limité de personnes, les places seront attribuées par le Comité d'organisation en octobre 1979 en fonction de l'ordre d'arrivée des demandes d'inscription.

Exposition

Une exposition intitulée "GEOEXPO 80" se tiendra sur les lieux mêmes du Congrès du 7 au 11 juillet 1980. Elle sera largement ouverte aux différentes institutions internationales qui y trouveront un lieu de rencontre privilégié avec les scientifiques venus du monde entier.

Programme social

Le déroulement à Paris du Congrès a permis aux organisateurs de mettre au point un programme très attractif pour les participants, ainsi qu'un programme spécial pour les membres accompagnants.

Etat d'avancement de la préparation du Congrès

La première circulaire a été diffusée en 80 000 exemplaires en octobre 1977. Au 1er décembre 1978, le Comité d'organisation avait reçu 5 800 réponses en provenance de 114 pays différents. Parmi ces réponses, environ 4 000 personnes demandaient à participer aux excursions. La deuxième circulaire est maintenant disponible et comporte le formulaire d'inscription définitif.

Les personnes intéressées par ce Congrès et qui désirent recevoir la 2ème circulaire sont priées de bien vouloir la réclamer au

Secrétariat Général du 26ème Congrès Géologique International
Maison de la Géologie
77—79, rue Claude Bernard
75005 PARIS — FRANCE

EL CONGRESO GEOLOGICO INTERNACIONAL viene celebrando sus sesiones cada cuatro anos, desde 1878. La 26a. sesion coincidira con la celebración del centenario de esta manifestación bajo los auspicios de la Unión Internacional de Ciencias Geológicas.

Comité de Organización: Presidente: Jean AUBOIN
Secretario General: Paul SANGNIER

Calendario:
— del 27 de junio al 6 de julio por la mañana, excursiones científicas antes del Congreso
— del 7 al 17 de julio: Sesiones del Congreso en el Palacio de Congresos de la Porte Maillot — Paris
— del 19 al 27 de julio: Excursiones científicas después del Congreso.

Programa científico

1°) *Sesión científica de apertura:* Los mas eminentes espicialistas sintetizaran cinco grandes temas relativos a la actualidad científica reciente.

2°) *Secciones:* El programa científico que se propone cubre prácticamente la totalidad del campo de las Ciencias de la Tierra. Está distribuido en 29 secciones El Comité de Organization ha velado por que los trabajos de las diferentes Asociaciones Científicas Internacionales, afiliadas a la Unión Internacional de Ciencias Geológicas estén integrados al programa del Congreso. Las propuestas de comunicaciones son libres y deben dirigirse a la Secretaría General antes del 1 de Octubre de 1979 para ser publicadas en el volumene de resumenes.

3°) *Coloquios:* Se ha elaborado el programa de los coloquios de modo que ilustre los principales temas de actualidad científica y económica del momento. Habrá siete, y estarán animados por científicos que figuran entre los mas ilustres. Las comunicaciones no podrán presentarse sino sobre invitación.

Excursiones

El Comité de Organización se ha asegurado el concurso de los Comités Nacionales de Geología de 18 paises europeos diferentes para presentar un programa atractivo de excursiones geológicas. Los temas seleccionados permiten proponer a los miembros del Congreso el conjunto de los aspectos geológicos de la Europa del Oeste. Es así como se proponen unas 85 excursiones diferentes, de una duración de 9 dias cada una, del 26 DE JUNIO al 6 DE JULIO de 1980, y del 19 DE JULIO al 26 DE JULIO de 1980. Las excursiones sólo permiten admitir un número limitado de personas, y las plazas serán atribuídas por el Comité de Organización en Octubre de 1979, en función del orden de llegada de las solicitudes de inscripción.

Exposición

Tendrá lugar una exposición titulada "GEOEXPO 80" en el mismo recinto del Congreso, del 7 al 11 de julio de 1980. Esta exposición estará ampliamente abierta a las diferentes Instituciones Internacionales que encontrarán en ella una opportunidad privilegiada de encuentro con los científicos del mundo entero.

Programa social

La celebración del Congreso en Paris ha permitido a los organizadores elaborar un programa muy atractivo para los participantes así como para los miembros acompañantes.

Estado de avance de la preparación del congreso

Le primera circular fue difundida en 80.000 ejemplares, en Octubre 1977. El 1 de Diciembre de 1978, el Comité de Organización había recibido 5 800 respuestas procedentes de 114 paises diferentes. Entre estas respuestas, 4 000 personas aproximadamente pedían participar en las excursiones. La segunda circular está ahora a disposición de los interesados y comprende el boletín de inscripción definitivo.

Se ruega a aquellas personas interesadas enel Congreso y que deseen recibir la 2a circular, se dirijan a

Secrétariat Général du 26ème Congrès Géologique International
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75005 PARIS — RFANCE

ACTA UNIVERSITATIS SZEGEDIENSIS

ACTA MINERALOGICA—PETROGRAPHICA

TOMUS XXIII

SZEGED, HUNGARIA
1977/78

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